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THE WHEELER FIRE IN RETROSPECT:

FACTORS AFFECTING FIRE SPREAD AND PERIMETER FORMATION

by

Anthony T. Dunn

and

Douglas Piirto

Submitted to the U. S. Forest Service in fulfillment of the terms of a Cooperative Agreement with Cal Poly to study factors affecting fire behavior on large fires in Southern California.

Natural Resources Management Department

California Polytechnic State University

San Luis Obispo

December 1987

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Final Report on
Coop Agmt. PSW-87-0017 CA
with PSW - Riverside Fire Lab

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ABSTRACT

Research was conducted on the various environmental factors affecting the behavior of the 1985 Wheeler #2 fire in Ventura County, California.

It was found that the Wheeler fire was subjected to a number of influences at different times and places and in various combinations that gave rise to diverse but often predictable and quantifiable behaviors. Primary among these was the influence of temperature and relative humidity on rate of spread. Also, interactions between local weather patterns (particularly the marine layer) and terrain were shown to have large influences on fire behavior. Roads and fuelbreaks appeared to be vital features in fire suppression, while the role of fuel age boundaries was shown to have had an insignificant effect on perimeter formation. Comparison of behavior on the Wheeler fire with historical fires in the area revealed repetitious patterns of weather, terrain and fuel interactions that may potentially be used on future fires for predicting possible fire behavior.

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INTRODUCTION

Purpose of Study

There is a growing realization today that the data collected in burn table and laboratory tests is by nature inadequate by itself for use in understanding the factors that affect the gross behavior of wildfires. While laboratory tests of fuel moisture, fuel size and distribution in the fuel bed are essential for understanding micro-scale fire behavior, they are of limited use in understanding meso- and macro-scale fire behavior on the landscape where weather, topography and gross scale fuel characteristics interact to determine fire behavior. Relatively little systematic observation or analysis of the actual effects of weather and other factors on the movement of fire across the landscape has been undertaken. Though valuable data that could be used for evaluating fire behavior exists (e.g. weather records, infrared photos, etc.), little is actually used to this end. Clearly documented or complete analyses of known fire behavior remain extremely rare.

The present study was undertaken to begin, in a limited way, to correct this situation. By correlating observed behavior of specific fires with known environmental conditions (weather, fuels, topography and suppression), we aimed to accomplish two obectives. First, to provide fire researchers and managers with a technique for collecting and quantifying fire behavior data. It is hoped that this technique will focus attention on the value of and need for more accurate fire behavior data. Standardized methods for collecting, storing and retrieving this data would be a valuable tool for fire researchers and managers, providing ready access to quantified fire behavior observations. Secondly, we hoped to begin providing insights to major guestions in fire behavior study that still remain to be seriously addressed, much less answered. Questions such as: What are the true effects of fuel age and type changes on fire behavior? How often do man-made obstructions and suppression efforts stop a fire and under what conditions? What role can weather changes play in determining fire perimeters?

Research based solely on laboratory work or computer modeling cannot begin to address these large-scale questions. What we call 'fire behavior' is a complex interaction of many factors, each having a varying effect on the movement of a fire, depending on existing environmental conditions. Without field validation of fire behavior, calibration of burn table results and computer models is impossible. Further, because of the complexity of the interactions between factors affecting fire behavior, research that focuses upon analyzing only one factor is bound to fail to fully grasp the relationships and interactions between the various factors that act on a fire to determine its behavior.

Instead of narrowing our focus in such a way, it was our intent to look at fire behavior from a much wider, 'gestalten,' perspective; viewing fire behavior as a whole composed of numerous tightly interacting factors. It was felt that although this was a highly intensive type of analysis, it had a greater potential of reflecting the respective roles of each fire behavior factor (weather, fuels, topography and suppression) than any other method. Though this project is merely a beginning, we hope it will serve as an example of a technique that has much to offer toward our understanding of fire behavior. We also hope, by raising questions and pointing in new directions, to stimulate inquiry into the varying roles and relationships between and among the factors that contribute to fire behavior in the chaparral in Southern California.

Review of Literature

Though each wildfire, no matter how small, has a fire report filed on it, little data is collected (and even less published) with the fire behavior analyst (who wishes to understand the specific factors that affect observed fire behavior) in mind. Fire reports include only basic data on fires and focus more on collecting statistics for evaluating suppression activities and fire losses than on any behavior that fires may express. Occasionally narrative accounts may be filed with fire reports, and these, though often incomplete, are gold mines for the fire behavior analyst. They are, however, sporadic and almost without exception unpublished. Systematic published accounts of observed fire behavior are even more rare, and are usually prepared for specific purposes such as evaluating conditions that resulted in fire fatalities (Countryman and others 1956, Countryman and others 1969, Schroeder and Taylor 1968).

Useful weather data is even more scarce. In most areas, fire weather data is collected at fire stations by station personnel. While this data is essential for calculating the level of fire danger, it has a number of drawbacks which severely reduce its usefulness to fire behavior analysts. First of all, these records are collected only once a day, usually at 1300 or 1400, even though weather patterns can change dramatically from morning to afternoon to evening and fires may occur at any time of the day. Secondly, weather can vary widely over small areas in the rugged, mountainous terrain of California, and the data collected at a fire weather station may bear little resemblance to the actual weather at the fire site. Thirdly, the very fact that fire weather data is collected at fire stations means that there will be no one at the station to take the weather when it is most needed--during large fires.

Weather data is often collected on large fires. It has, however, a number of drawbacks for use in fire behavior analysis. Few if any permanant sites are set up and readings are taken at

irregular intervals, making it difficult to establish patterns of weather change for any one location. Also, this data is almost always kept with the fire package, limiting its use only to those with access to the fire package. And as fire packages are generally discarded after five years, this data is rarely available to the fire historian.

While a large body of literature exists on the topic of fire weather (Coffin 1959, Fosberg and others 1966, Schroeder 1960, 1961, Schroeder and others 1964), few papers are devoted to the specific role of weather in the actual observed behavior of fires. Annual summaries of fire weather exist (Countryman 1957, Pirsko 1960, 1962), but these are of only general use to the fire behavior analyst. The most detailed and useful accounts of the effects of weather on fire behavior are found again in the narrative accounts that accompany some fire reports and the reports filed concerning fire fatalities. Other papers (Albini 1983, Rothermel 1983, Salazar and Bradshaw 1984) focus on fire weather prediction rather than the description of actual observed effects of weather, and so are little use for our purpose.

Most literature pertaining to fire behavior addresses the problems of fire behavior prediction rather than evaluation. A large body of writing has arisen on the topic of predicting fire behavior (Albini 1976, Albini 1983, Cohen 1986, Deeming and others 1977, Rothermal 1972, Rothermal and Philpot 1973, Rothermal 1983, U.S. Dept. of Ag. 1963), and though this material is essential for fire suppression purposes, little of it is useful in evaluating the causes of observed behavior. The focus on prediction over evaluation has created a situation where, with few exceptions, little quantified data can be found concerning the specific causes of observed fire behavior outside of the occasional narrative report or analysis of weather. As far as comprehensive discussions of the effects of external factors on fire behavior goes, textbooks (Brown and Davis 1973, Chandler and others 1983, Clar and Chatten 1975, Pyne 1984) appear to be one of the few places where this topic is given any serious coverage; a gauge of how persuasive the emphasis on prediction has become. Even the textbooks fall far short of being of any use to the behavior analyst as they are merely descriptive in nature and offer little quantified data to support their concepts. In essence, a virtual desert exists concerning the systematic evaluation and quantification of the causes of observable fire behavior.

METHODS

Specific Case Selection

There are essentially two ways to study actual wildfire behavior: observe fires as they occur and record data on-site; or compile and analyze data collected during previous fires. The first method is perhaps the more desirable of the two, since it is possible to control the quality and type of data collected. It was our intent to employ both methods on this project. However, there were no large fires in Southern California during the data collection phase of this project, and we were, therefore, limited to studying historical fires. Time and resource limitations further limited research to a single case study.

The first step of the project was to formulate a set of criteria for the selection of the specific fire that we were to study. The final set of criteria used in the selection of candidate fires for our case study were:

1. The fire must be relatively recent (after 1977)
2. The fire must be in Southern California
3. The fire must be a large fire (over 10,000 acres)
4. The fire should be one that is fairly well known

Once these criteria were met, it became necessary to assess the availability of documentation needed to conduct our research. This, actually, was the most important criteria for choosing our case study and by itself eliminated virtually all fires over five years old since their documentation had been typically discarded. The types of documentation that we were concerned with included narrative fire reports, a fire package including shift plans and fire spread maps, good quality weather records from the area of the fire, aerial and infrared photos, fire history data, published literature, vegetation type information, and people who had been on the fire. After reviewing about a half dozen candidate fires, we concluded that the 1985 Wheeler #2 fire (herein referred to as the Wheeler fire) on the Los Padres National Forest was the best suited to our purposes. The Wheeler fire began at about 3:00 in the afternoon on Monday, July 1, 1985, during one of the most severe periods of fire weather in California history. By the time it was finally contained, it had consumed 107,828 acres (118,000 acres, officially), destroyed 15 homes and cost nearly $9 million dollars in suppression. It was also the largest fire in California since 1977 (In the summer of 1987, the Stanislaus complex of fires consumed 145,980 acres.).

No two fires are identical, and this holds true for the available information pertaining to each fire. In many ways the Wheeler fire was exception in the way of documentation. Virtually every type of needed data was available for the Wheeler fire, from infrared aerial photos to accurate hourly weather data. The Wheeler fire was choosen for this study precisely on the basis of the availabilty of this type of information. However, for most fires, only a fraction of this type of data is available, limiting the type and depth of research that can be done. Therefore, the methods used in this study will differ somewhat from every other case study in that research can only be conducted to extent of the data available. Still, though perhaps exceptional, the Wheeler fire serves as an example of what can be accomplished with an 'ex post facto' study procedure. The more case studies that are conducted along these lines, the better we will be able to define the types and quality of data necessary to yield results that shed light on fire behavior. Unfortunately, at this time, there are probably not more than one or two fires per year in California that have sufficient documentation to allow the level of research attempted in this study.

Limitations

Though there is much that can be learned from specific case studies of fire behavior, it must be recognized that there are also practical limitations to this procedure. The first limitations, of course, are those imposed by the type and quality of data available for analysis. Fire behavior analysis requires extremely accurate and comprehensive data in order to reconstruct an accurate picture of a fire and its enviroment. However, virtually all data collected on wildfires is intended for use in the immediate suppression of the fire and is not geared toward the purposes of the fire behavior analyst. Some types of data vital to fire behavior analysis are not pertinent for suppression purposes and often go uncollected. In this particular case, as already noted, a wide variety of relevant and accurate data was available, but data quality and availability is a major limiting factor in any fire behavior analysis.

The following is a brief list of some of the data limitations that the fire behavior analyst may encounter in attempting this type of research.

Weather data. Since most large fires occur in rather sparsely populated areas, relevant and timely weather data is often non-existent. This is often the major limitation in fire behavior study.

Spread data. Fire spread maps prepared on a fire can be a valuable resource. These maps are usually based on information from scouts, and though often accurate, problems such as poor visibility, lack of accessibility, rugged terrain and rapid fire

spread may reduce their accuracy. Generally speaking, infrared aerial photos are the most reliable source of spread data.

Historical fire maps. These are of highly variable quality; the older the map, the more suspect the quality. Typically, fire maps only indicate the primary, or exterior, perimeter as this is the only one of importance for suppression purposes. Unburned islands within fires are often omitted. Again, aerial photos (when available) are often the most reliable source.

The other type of limitation on the value of this type of research springs from its very nature: that of being a case study. Case studies lack the statistical certainty of large population studies. While this prevents the establishment of the "prevalence" or pattern of certain expressed behavior characteristics, it also prevents the masking of unique factors (such as sundowner winds) by more common or widespread traits. For example, while it may be statistically accurate to state that the majority of large wildfires in Southern California occur under Santa Ana conditions, this very statement masks the fact that large and destructive fires also commonly occur under other weather conditions. It is necessary to realize in this particular respect that there is a trade off between case and large population studies; between specificity and large scale generalizations. While the specificity of case studies may limit their geographical, vegetational and climatologial usefulness, large population studies cannot, by their very nature, be used for prediction in site-specific situations. With more widespread use of detailed case studies, it may be possible to better define the roles of geographical, vegetational and climatic variation on fire behavior throughout the state.

Information Sources

Since a primary goal of this project was to examine the relationships between fire spread, perimeter formation and environmental factors, it was necessary to obtain two types of information: first, accurate quantitative data on the spread and perimeter of the fire; and second, accurate environmental data (such as weather, fuel and terrain data).

The first type of information was provided by a series of high-resolution black and white infrared (IR) aerial photos taken of the Wheeler fire from the evening of July 3, 1985 through July 15, 1985. Table 1 lists the dates and times of each IR flight. The negatives of these photos were found with the Wheeler fire fire package at the Ojai Ranger District Office. In addition, infrared U-2 photos taken on July 2nd, and infrared Landsat photos taken on the morning of July 3rd were used for fire spread analysis. The final perimeter of the fire was mapped onto 7 1/2 minute topographic maps from 1/24,000 scale color aerial photos taken on July 23 and August 8, 1985 using a stereoscope. The

extent of the fire during each burn period (the period between each set of IR photos; see Table 1) was plotted from the IR photos onto the final perimeter map. This was done by hand as the IR photos all exhibited a certain amount of distortion. A Tektronix digitizer was used to calculate the area consumed during each burn period. Average rates of spread for each burn period were calculated by dividing the total area burned during the burn period by the number of hours in that period. This gave rates of spread in terms of acres per hour rather than the linear terms of chains per hour more commonly used in fire behavior models.

Environmental data was collected from a number of different sources and was more variable in quality than the highly accurate spread data. Primary for our purposes was the collection of accurate and relevant weather data. Though there were a number of weather observations taken by fire personnel during the Wheeler fire, it was found that this data was of very limited value. Observations were sporadic and rarely taken at the same location twice, giving very little picture of the patterns of weather change at any given place. Also, many observations lacked such vital data as the date, time or location. However, there were a number of other sources of weather data available, predominantly from county and local governmental agencies. Table 2 and Figure 1 show the location, type and sources of weather data used for this report. Though there was only one weather station located behind the front range area, the available sources were sufficient to give us an accurate picture of the major weather changes during the fire. In addition, twelve-hourly upper air maps were obtained from the National Weather Service office in Riverside, CA. These maps allowed us to follow the major synoptic patterns of air movement over the Pacific Ocean and Western United States for the duration of the fire.

Vegetation data for the area of the Wheeler fire was obtained from the VTM (Vegetation Type Map) survey blue-line maps. The field work for these maps was carried out in the early 1930's and their reliability varies from excellent to poor, depending on the particular map in question. The VTM maps break down California vegetation into twenty major types, twelve of which occurred within the perimeter of the Wheeler fire. Despite the obvious drawbacks, we used the VTM maps because there is no newer, more accurate vegetation type data available for the area of the fire. Casual comparison of the VTM maps with recent aerial photos suggests that the VTM data is still accurate.

By far the most potentially unreliable data used in this report are the maps of historical fires in the area of the Wheeler fire. Dunn (1987) points out the many drawbacks of early and even recent fire maps. Suffice to say here that since no other more accurate source of fire history data was available, only the original fire maps and reports were used in this report. These records are kept on file in the Supervisor's Office of the Los Padres National Forest in Goleta.

Table 1. Dates and times of infrared (IR) aerial photo and satellite flyovers on the Wheeler fire. Times are to within the nearest hour. A flyover of the Wheeler fire typically took about 45 minutes.

DATE	TIME	NOTES
July 2, 1985	1500	U2 aircraft flyover. Color IR
July 3, 1985	1000	Landsat satellite flyover. Color IR
July 3, 1985	2100	B&W IR, oblique perspective
July 4, 1985	1400	B&W IR, vertical perspective
July 4, 1985	2100	B&W IR, vertical perspective
July 5, 1985	1400	B&W IR, vertical perspective
July 5, 1985	2200	B&W IR, vertical perspective
July 6, 1985	1000	B&W IR, vertical perspective
July 6, 1985	2100	B&W IR, vertical perspective
July 7, 1985	1000	B&W IR, vertical perspective
July 7, 1985	2100	B&W IR, vertical perspective
July 8, 1985	1000	B&W IR, vertical perspective
July 8, 1985	2100	B&W IR, vertical perspective
July 9, 1985	2000	B&W IR, vertical perspective
July 10, 1985	1800	B&W IR, vertical perspective
July 13, 1985	0100	B&W IR, vertical perspective
July 13, 1985	1400	B&W IR, vertical perspective
July 13, 1985	2100	B&W IR, vertical perspective
July 15, 1985	0900	B&W IR, vertical perspective

Table 2. Sources of weather data for the period of July 1, 1985 through July 15, 1985.

LOCATION	SOURCE	TYPE OF DATA
El Rio	1	RH; Temp; Wind Direction & Speed
Emma Wood St. Beach	1	Wind Direction & Speed
Lake Casitas	6	Maximum & Minimum Temp; Evaporation
Matilija Dam	2	RH, Temp
Ojai	1	RH; Temp; Wind Direction & Speed
Ojai	3	Fuel Stick Moisture; RH; Temp; Wind Direction & Speed
Oxnard (1400-0400)	7	Visibility; Temp; Dew Point; Wind Direction & Speed
Piru	1	RH; Temp; Wind Direction & Speed
Santa Barbara	4	Wind Direction & Speed
Santa Barbara Airport	7	Visibility; Pressure; Dew Point; RH; Temp; Wind Direction & Speed;
Santa Barbara Harbour	5	Visibility; Wind Direction & Speed; Temp; RH; Pressure
Simi Valley	1	RH; Temp; Wind Direction & Speed
Ventura Harbour	5	Visibility; Wind Direction & Speed; Temp; Pressure

SOURCES

1) Ventura County Air Pollution Control District, Ventura, CA
   Frequency of Observation: Hourly

2) Ventura County Flood Control & Water Resources, Ventura, CA
   Frequency of Observation: Continuous (hygro-thermograph)

3) Ventura County Fire Protection District, Ventura, CA
   Frequency of Observation: 0900, 1300 and 1700 hours

4) California Air Resources Board, Sacramento, CA
   Frequency of Observation: Hourly

5) California Air Resources Board, Sacramento, CA
   Frequency of Observation: Three Hourly

6) State of California, Dept. of Water Resources, Sacramento, CA
   Frequency of Observation: Daily

7) U.S. Dept. of Commerce, NOAA, Ashville, NC
   Frequency of Observation: Hourly

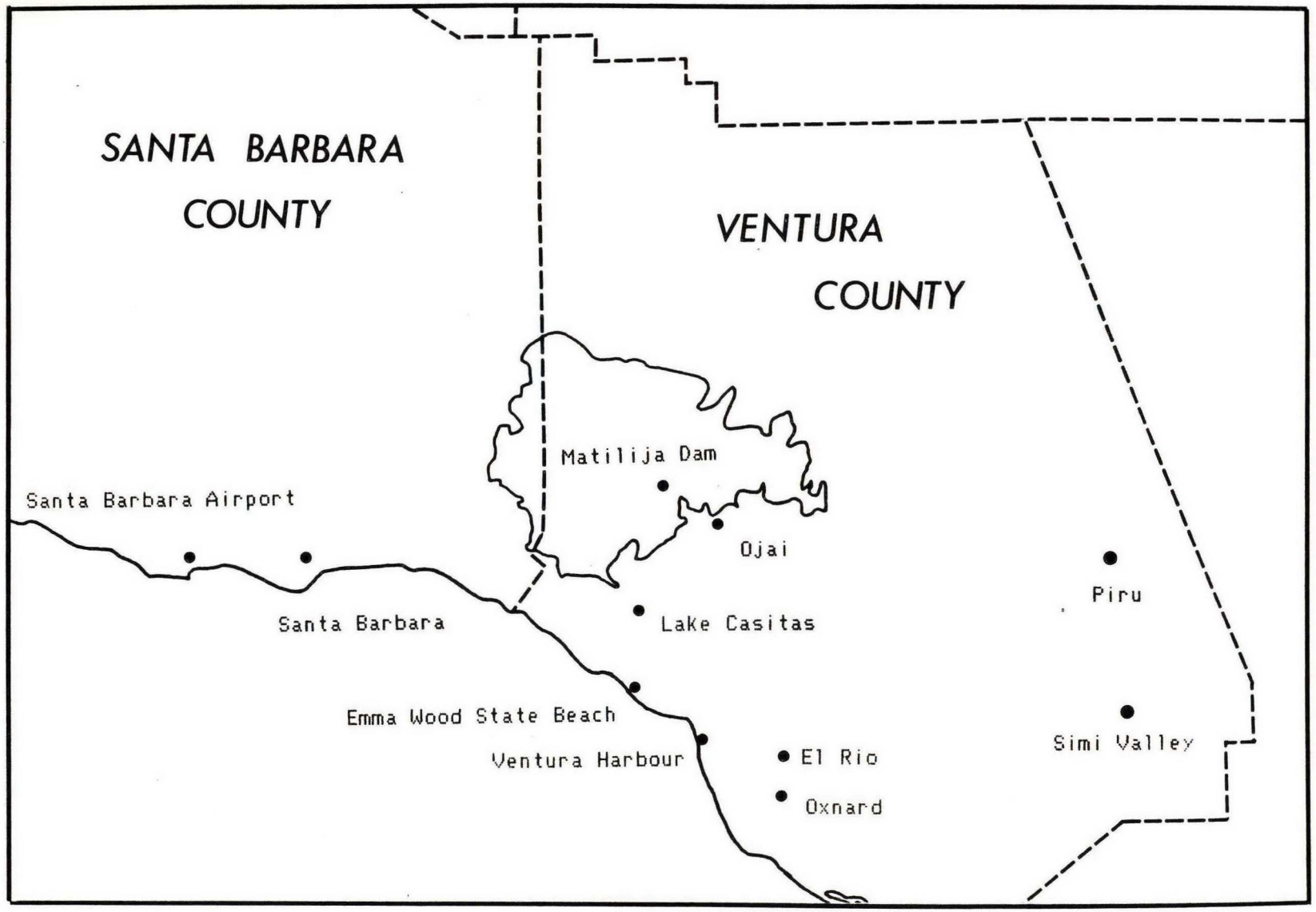


Figure 1. Location of weather stations used in analysis of Wheeler fire weather patterns.

In addition to the above data, interviews with Fritz Cahill (Fire Behavior Officer, Los Padres NF) and Dick Pacheco (AFMO, Ojai Ranger District, Los Padres NF) were conducted in July 1987. These interviews were valuable in providing detailed information of the early behavior of the fire. However, because of the length of time that had elapsed since the fire, it was not felt that interviewing should be used as a major data collection tool in the case of the Wheeler fire.

SETTING

The fire environment of Southern California is perhaps the most diverse and complex of any area in the world. Specific locations, with unique associations of vegetation, terrain or climate, may exhibit endemic fire environments with their own particular "quirks" and fire behavior potential. This situation at once decreases the value of large-scale generalizations of fire behavior in California and increases the value of studying site-specific histories of fire behavior.

Fires do not just happen, they happen in some context, and attempting to understand fire behavior without first examining the context in which it occurs can be misleading or, at worst, useless. With this in mind, this section will attempt to "set the stage" for the Wheeler fire by describing, in general terms, the characteristics of the fire environment in the area. Detailed discussion of the actual environmental conditions existing at the time of the fire, and their specific roles in influencing the behavior of the fire, follows in the section specifically addressing the Wheeler fire.

Background and History

Location

Terrain. The Wheeler fire originated in the Transverse Ranges of Southern California, in west central Ventura County (Figure 2). It is an area of extreme ruggedness and inaccessibility, where slopes often exceed 100 percent. With the exception of Highway 33, there are no paved roads in the Wheeler fire area, and much of the area is de facto wilderness due to the lack of access and steep terrain. Behind Ojai and Capenteria, Nordhoff Ridge and the eastern end of the Santa Ynez Mountains (the so-called 'front ranges') rise abruptly to elevations of over 4000 feet (Figure 3). Between these two ranges flows the Ventura River, formed by the confluence of Matilija and Wheeler canyons, the major drainages in the area of the fire. These deep, narrow canyons are in turn ringed by peaks, ranging up to the 6000 foot high Monte Arido in eastern Santa Barbara County. To the north lies Highway 33 and Sespe Creek; to the east, the rugged Topatopa Mountains.

Vegetation. The vegetation patterns in the area of the Wheeler fire follow the pattern found throughout most of Southern California, with grassland and coastal scrub at lower elevations and on dry slopes (particularly in the area of Ojai and Lake Casitas), oaks in the canyon bottoms and conifers (primarily bigcone spruce) on north slopes at higher elevations. In between, chaparral dominates as the most common fuel type, with various associations carpeting about 85 percent of the land in the area of the fire. As elsewhere, chamise chaparral is most common on dryer slopes while mixed chaparral (consisting of ceanothus, manzanita,

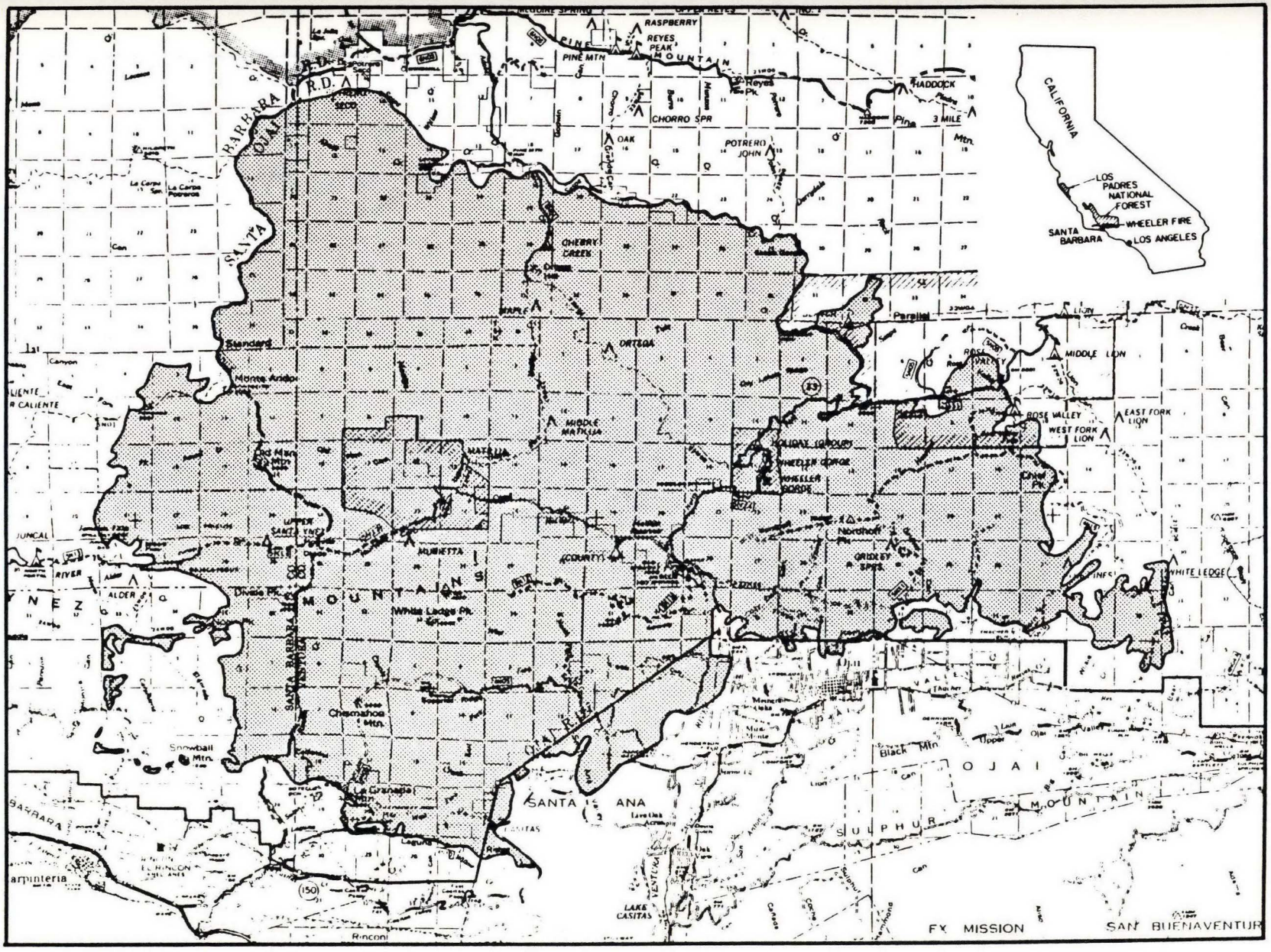


Figure 2. Map of the Wheeler fire area.

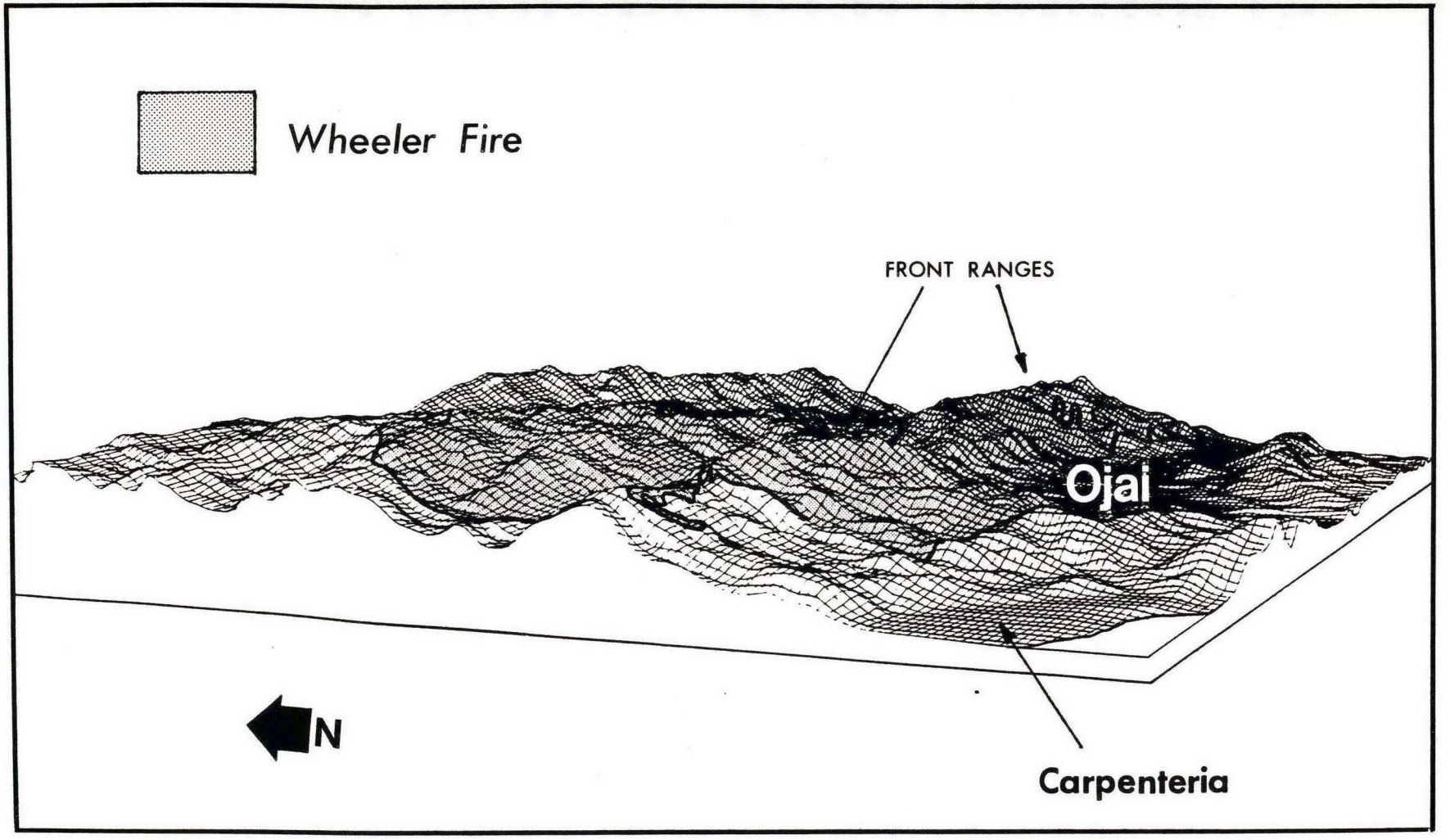


Figure 3. Perspective map of the Wheeler fire area. View is from the southwest at an altitude of 10,000 feet. Note the position of the front ranges.

scrub oak and other species) is more common on the moister north-facing slopes. In the more inland areas, a drier, more open "semi-desert" chaparral association becomes increasingly common, as does pinon-juniper woodland.

Climate. The Climate of the Wheeler fire area is typically Mediterranean in nature, with hot, dry summers and cool, moist winters. Annual rainfall increases with altitude from 15.2 inches at Ventura and 21.4 inches at Ojai, to over 40 inches in the Monte Arido area (Figure 4; State of California 1981). The front ranges are a major climatic feature of the area, isolating the inland areas from the moderating influence of the ocean. On the ocean side of the front ranges, mild temperatures and extensive periods of fog and low clouds prevail throughout the summer months. Humidities commonly hover near 100 percent at night. When the marine layer is especially deep, it may penetrate as far as Matilija and Wheeler canyons.

The climate of the interior area is much less moderate. High temperatures of 100° F during the summer months are common. And though precipitation is generally higher than along the coast, the lack of fog gives rise to extremely dry summers. Some differences in climate can be seen in Table 3, which lists the average June and July temperatures for a number of coastal and inland stations in the area.

A climatic characteristic that is unique to the Wheeler fire area is the "sundowner" wind. As the name suggests, these winds occur after sunset, along the front ranges between Gaviota and Ojai. The sundowner wind is an often severe and turbulent downslope wind, frequently accompanied by high temperatures and low humidities. Wind speeds of over 60 miles per hour have been recorded. With the onset of a sundowner along the coast, the usual onshore flow of marine air is reversed; the wind blows strongly out of the north, temperatures may rise as much as 30° F and humidities may drop by up to 50 percent within one hour (Ryan 1977). During the 1971 Romero fire in Santa Barbara County, violent sundowner winds were responsible for the death of a tractor operator and three tractor bosses.

Very little research has been done on the sundowner phenomenon. It is still unclear what the source of these winds are, though they may be a result of post-sunset subsidence of warm air over the southern portion of the San Joaquin Valley; in essence a mini-Santa Ana. On the average, three or four strong sundowers may occur each year during the summer and early fall months (Ryan 1977).

Characteristics of historical fires

As stated before, fires don't just happen; they happen in some context. Close scrutiny of historical fire behavior in a particular area can reveal a great deal about the nature of the "context" in which those fires occurred. A fire behavior feature

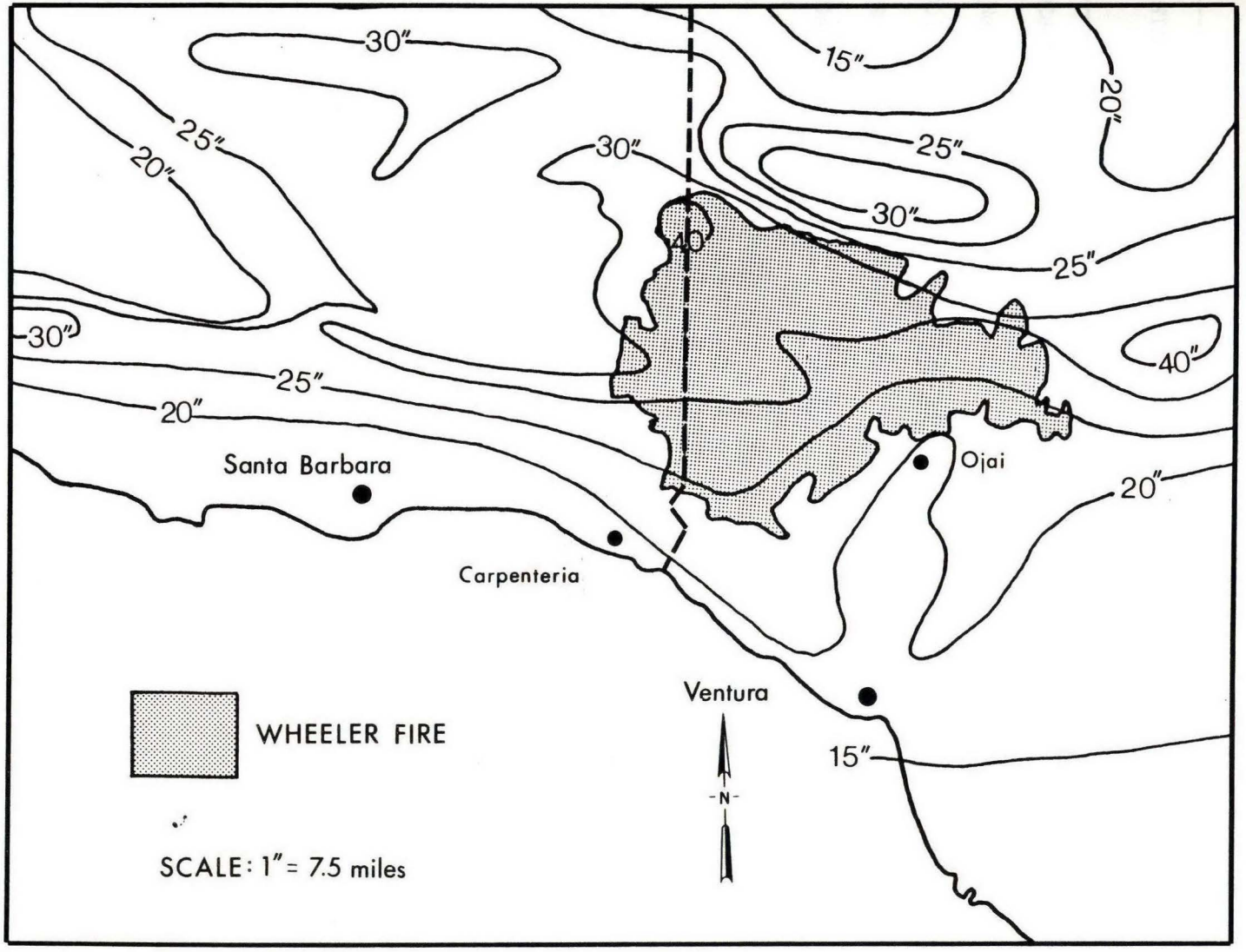


Figure 4. Mean annual precipitation in the Wheeler fire area.

SOURCE: State of California 1981

Table 3. Average June and July temperatures for selected stations in Santa Barbara and Ventura counties.

STATION	LOCATION	JUNE AVG.	JULY AVG.
Cachuma Lake	Inland	70.7° F	75.3° F
New Cuyama	Inland	72.2	77.2
Ojai	Semi-coastal	67.3	73.3
Santa Barbara	Coastal	63.5	66.6
Santa Paula	Coastal	64.3	67.6

that may appear singular or unusual on a particular fire may actually emerge as a common characteristic (such as sundowner winds) when the behavior of other fires in the area is examined. A detailed knowledge of historical fire behavior can provide potent clues to the fire manager of what kind of behavior to expect and under what conditions.

Fortunately, detailed narrative reports exist for a number of large fires in the Wheeler fire area. This, coupled with fire maps and weather data (where available) provides us with sufficient data to conduct an analysis of at least a few of the larger fires. The following sections outline the histories of these fires, highlighting some of the notable fire behavior features of each. Table 4 lists the dates and acreages of the major fires in the Wheeler fire area.

The 1932 Matilija fire. The Matilija fire burned nearly 220,000 acres and remains the largest fire in California history (Figure 5). Analysis of the career of the fire is difficult in that detailed fire spread and weather information are almost nonexistent. What records that do exist suggest that the Matilija fire occurred under an extended though fairly moderate subtropical high aloft, or "heatwave" condition. Surface air maps (Figure 6) show the presence of high pressure off the coast of California for the duration of the fire. That and the thermal low over the interior of the state are typical of the subtropical high aloft condition (Schroeder and others 1964). However long the heatwave persisted, temperatures at Santa Barbara, which never exceeded 81^{o}, suggest that it was not an overly severe one. This is supported by the surface air maps which indicate morning coastal fog at Los Angeles for nine of the eleven days of the fire. This is in direct contrast to Pyne's (1982) account of the fire which states that "gale force Santa Ana winds drove the fire in a wild rush to the sea..." None of the sources used in this report, including the official fire narrative (on file at the Los Padres NF, Goleta) and surface air maps, support Pyne's contention of Santa Ana conditions. Nor does the rest of his description of the fire jibe with existing narrative reports or spread maps. On the other hand, Hutchinson's (1933) account of the fire is lifted almost entirely from the official narrative.

The Matilija fire began at approximately 0700 on September 7, 1932 from an abandoned campfire on the North Fork Matilija Creek. Due to the remote nature of the area the fire went unreported until 1000, when it was spotted from La Cumbre lookout, 21 miles west of the fire. By the time the first person arrived at the fire (around noon), it had burned about 300 acres in mixed chaparral and was spreading upslope to the west. The temperature at Matilija Dam stood at 98^{o} F. By 1600, reinforcements were beginning to make the five mile foot or horse trek up Matilija Canyon, and the fire had consumed about 600 acres. At around 1700 a "sudden change in conditions in the fire area caused a surge which spread the fire southeast and southwest very rapidly, continuing until 12:00 p.m. [sic, midnight], burning approximately

Table 4. A list of major wildfires from 1911 to 1984 in the area of the 1985 Wheeler fire. All locations are from the San Bernardino Base and Meridian.

FIRE	DATE	SIZE (ACRES)	LOCATION OF ORIGIN
Casitas	11-19-25	6,400	T4N R24W Sec. 34
Matilija	09-07-32	219,254	T5N R24W Sec. 11
Wheeler Springs	09-12-48	25,885	T5N R23W Sec. 16
Coyote	09-22-64	67,000	T4N R27W Sec. 1
Romero	10-06-71	14,538	T4N R26W Sec. 3
Bear	08-22-72	17,150	T5N R21W Sec. 5
Cozy Dell	09-25-78	910	T5N R23W Sec. 28
Matilija	07-07-83	4,600	T5N R24W Sec. 22

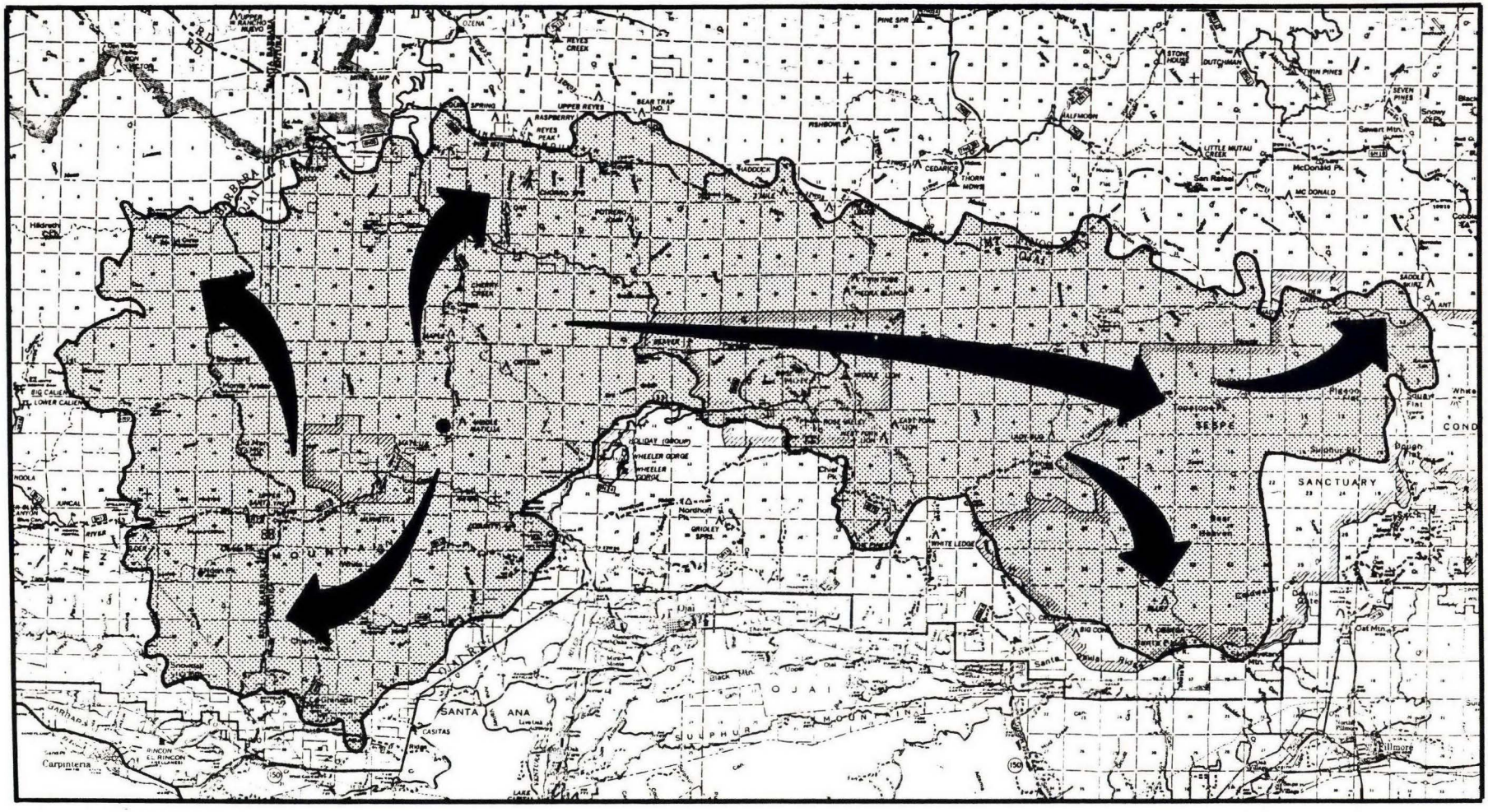


Figure 5. The 1932 Matilija fire.

Scale: 1" = 4.35 miles. ●: Fire Origin

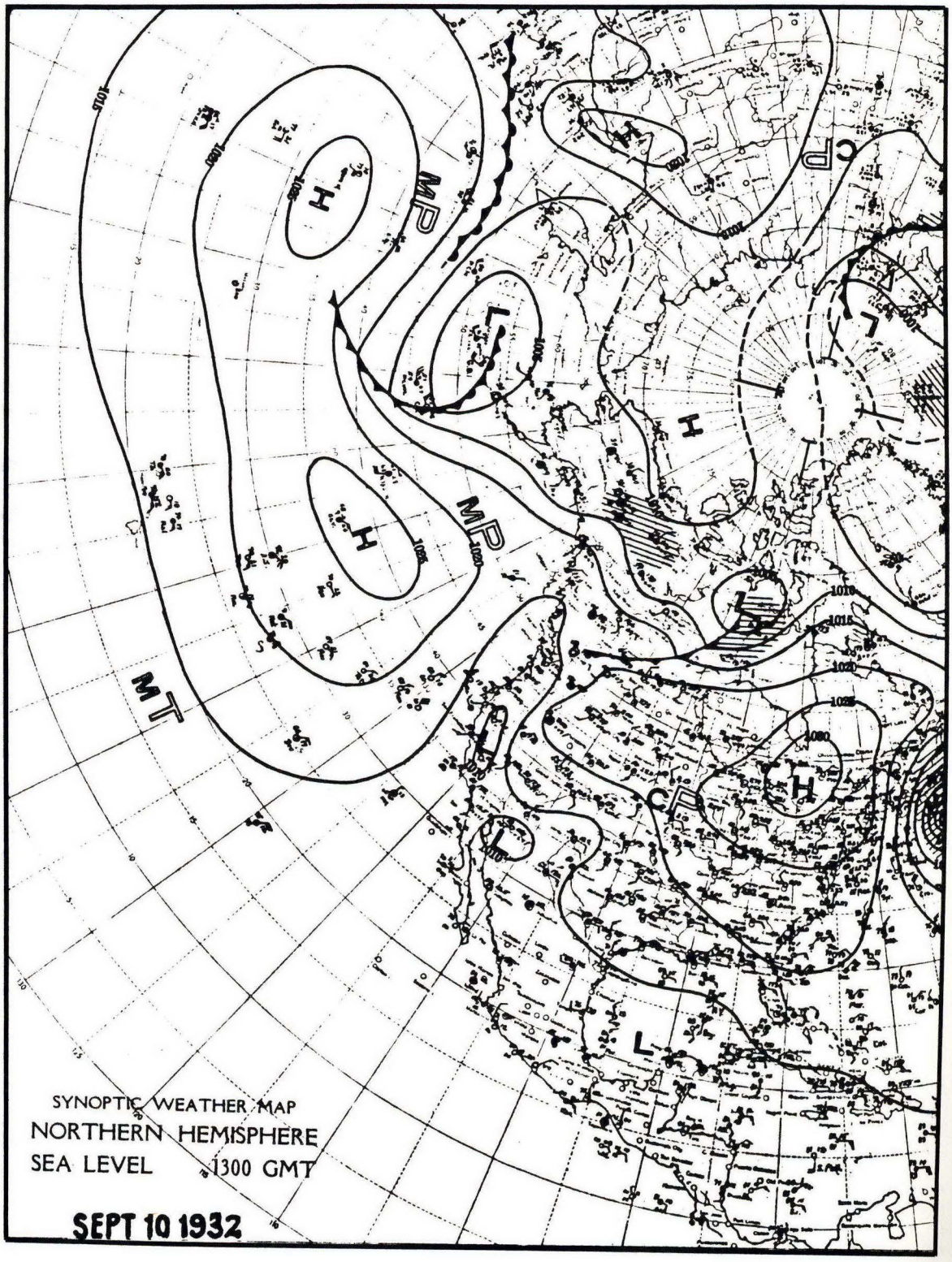


Figure 6. Surface air map, September 10, 1932.

20,000 acres" (Matilija narrative). Though occurring behind the front ranges, this would appear to be a fairly typical sundowner condition, occurring in the evening with strong off-shore winds. By 1800, the fire had crossed to the south side of Matilija Canyon, spreading on two fronts; one toward Matilija Dam and the other toward the Murietta Divide. At 2100, the west front of the fire was reported to have crossed Divide Peak.

By the morning of the 8th, the fire had consumed over 28,000 acres, but had ceased spreading to the south as it encountered a very strong marine layer. During the day, the fire continued to spread actively, primarily to the west and northwest. By midnight of September 8, the fire stood at about 36,000 acres. By 1200 on the 9th, the entire southern perimeter of the fire, from Matilija Dam to Snowball Peak, was reported as cold, though the northwest front continued active. By midnight on September 9, the fire had grown to nearly 50,000 acres and its northern front extended from Old Man Mountain to Ortega Hill and on to Dry Lakes Ridge.

The day of September 10 saw what has to be some of the most severe fire behavior in California history. Unfortunately, there are no weather records that can even give us a glimmer of what happened, perforce reducing this account from the analytical to the speculative and merely descriptive. On the morning of the 10th, the fire's active front was located between Sespe Gorge and Dry Lakes Ridge. "All hell broke loose at noon. A forty-mile gale swept over the mountains carrying the fire eastward across the Sespe River into the Pine Mountain Lodge, Mutau Flats and Devil's Heart country. In one hour the wild flames traveled twelve miles on a front five miles wide" (Hutchinson 1933). Unbelievable as it seems, this account is supported by all existing records. It should be noted that this advance was made directly down the length of the canyon of Sespe Creek. A possible explanation for the sudden run might be the surfacing of a low-level jet, an unpredictable condition known to cause extreme fire behavior in California (Ryan and others 1971). Whatever the cause, by evening the fire had consumed over 30,000 acres and suppression forces had been thrown into total disarray. Open line extended from Rose Valley Road east to Devil's Heart Peak and from there northwest to Pine Mountain Lodge, west to Monte Arido and south to Noon Peak, about 100 miles total.

On September 11, a generally southwest wind pushed the west front of the fire into the Juncal drainage and the northwest front began advancing toward Potrero Seco. By midnight the fire had blackened another 20,000 acres, a total of 100,000 acres in five days. For the next few days the fire burned erratically, burning the Reyes Peak lookout on the 13th and spreading on the open lines in virtually all directions. By the end of September 15, the Matilija fire had consumed over 160,000 acres.

On the evening of the 16th the fire made a rapid advance south from the crest of the Topatopa Mountains toward Santa Paula Peak, blackening another 30,000 acres; another possible sundowner

condition. On the 17th, the fire made its last major advances, to the south near Santa Paula Peak, to the east near Pigeon Flat and to the west in the Caliente Creek drainage. Weather conditions on the 18th were "somewhat more favorable" with higher humidities, and line construction proceeded with greater success. By September 20, the fire was considered corraled and by 1700 on the 24th, it was declared controlled at 219,254 acres.

Despite the lack of solid and cogent data on the Matilija fire, it is possible to make some valuable observations. First of all, though the fire occurred under 11 days of a fairly stable and unchanging weather pattern, it exhibited extremely variable and unpredictable behavior. This may be accounted for in part by the fact that the subtropical high aloft condition does not generate large-scale wind patterns. Therefore, most winds tend to be local in nature and arise from a combination of topography and convectional heating. Much of the multi-directional spread of the fire can be attributed local topographic configurations. In many cases, the fire itself was noted to have generated anomalous and extreme local conditions, overriding the existing weather. Perhaps the major run of the fire was triggered by fire affected weather conditions. Also, the fire was by and large restricted to the area behind the front ranges. It is apparent that conditions along the coast during the fire were quite moderate and that only the interior areas were strongly affected by the heatwave. The only cases in which the fire advanced toward the coast were under conditions resembling sundowner winds.

Comparisons between the Matilija fire and the Wheeler fire are difficult to make, even though they burned much of the same area. Still, there is an unsettling similarity between their major advances. Both began suddenly during the late morning and had spent themselves (after consuming about 30,000 acres) by late evening. Lateral spread during these advances were twelve miles and seven miles for the Matilija and Wheeler fires, respectively. Of course, the runs were made in opposite directions, but the underlaying mechanism driving such rapid advances may be the same.

The 1948 Wheeler Springs fire. The Wheeler Springs fire (Figure 7) began about a mile west of the 1985 Wheeler fire and had a very similar early career. Unfortunately, weather data for the period of the Wheeler Springs fire was unavailable, severely limiting analysis of fire behavior. Still, existing records suggest that it occurred under a moderate to strong subtropical high aloft condition. The fire began at 1452 on September 12th from a malfunctioning butane system at the Wheeler Springs Resort, on the north side of Highway 33. At the time of the fire's origin, most of the fire crews of the Ojai District were on the Sespe fire, a 25 acre blaze which had begun early on the morning of the 12th. Fortunately, a tanker crew from Santa Barbara had been moved in to cover Wheeler Gorge and they were the first to respond to the fire. At the time of initial attack, the fire was at ten acres and making a run up the canyon on the north side of the highway in 16 year old fuels.

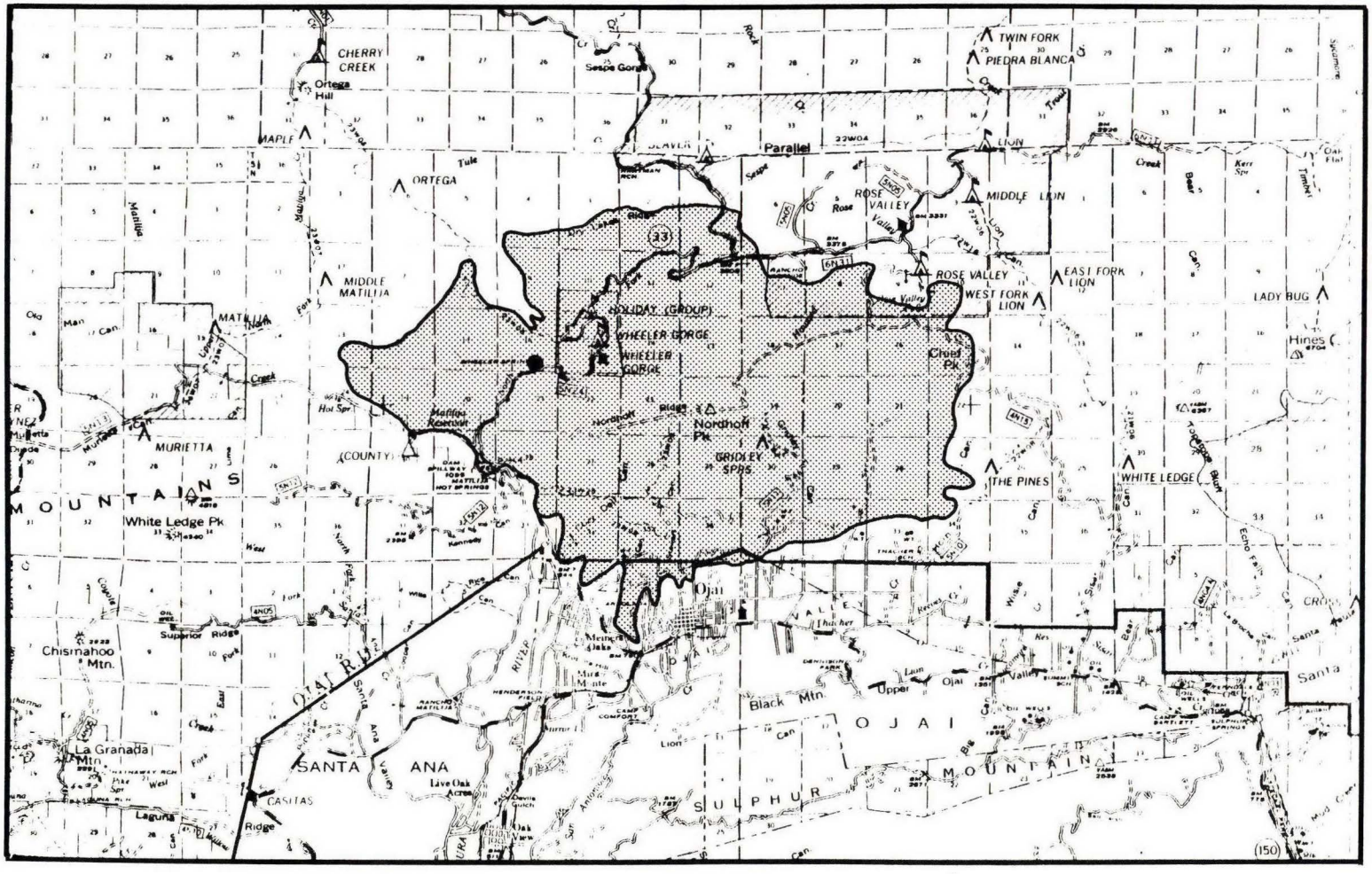


Figure 7. The 1948 Wheeler Springs fire.

Scale: 1" = 2.75 miles. ●: Fire Origin

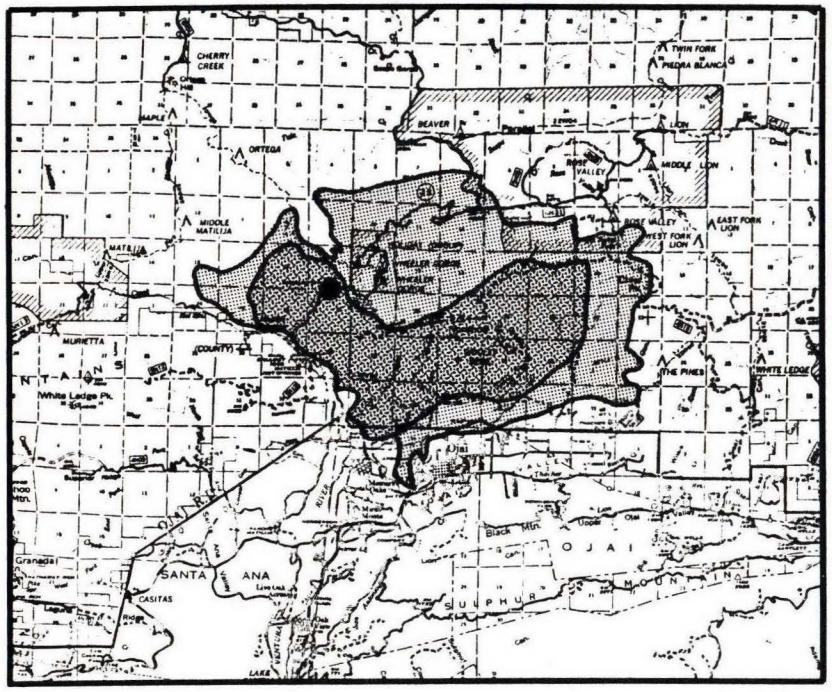
At around 1800, the wind (which had been mostly upcanyon) turned and began blowing out of the north. The fire began moving back towards Wheeler Springs Resort. Between 1835 and 1845, the fire spotted across the highway and began a rapid run up Nordhoff Ridge. By 2000 the fire had crested Nordhoff Ridge west of Nordhoff Peak and had begun backing actively into Cozy Dell Canyon, pushed by sundowner winds. In its first five hours, the fire had burned about 1750 acres. The fire burned strongly until about 0400 on September 13, when the sundowner winds ceased.

The fire burned actively but moderately during the day of the 13th, threatening to cross the highway near Matilija Dam. By 1800, the fire had burned over 9500 acres. Again at about 1800, sundowner winds set in and the entire south front of the fire, from Cozy Dell to Gridley Canyon, became very active, pushing rapidly into the outskirts of Ojai and Meiners Oaks. Around 0200 on the 14th the fire began to die down as the sundowner winds left the area.

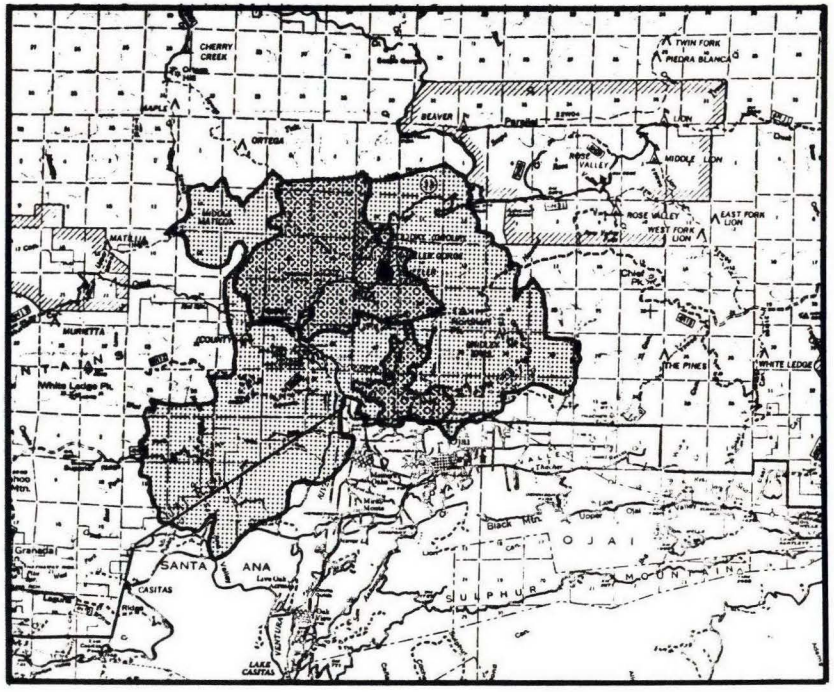
By the morning of the 14th, the fire had begun burning into Senior Canyon and backfiring began there about noon to protect threatened structures. During the day, the fire became very active on the inland side of the mountains, with major runs north of Matilija Creek and Wheeler Gorge. Between 1300 and 1800 on the 14th, the fire made its most rapid advance, burning from Wheeler Gorge east into the Howard Creek drainage, a distance of nearly four miles.

Though we lack weather records, it is clear that by the evening of September 14 the marine layer was moving into the fire area, and "the humidity increase was very noticable in Ojai" (Wheeler Springs narrative). With the influx of the marine layer, there was no recurrence of sundowner winds. The fire began laying down on all fronts and by the morning of the 15th there was fog in the Ojai Valley. Active line construction began all along the perimeter and the fire made no further progress. By 1800 on September 16, the fire was declared controlled at 25,885 acres.

The behavior of the Wheeler Springs fire was remarkably similar to the early behavior of the 1985 Wheeler fire (Figure 8). Both fires originated on the north side of Highway 33 in the mid-afternoon and spotted across to the south side to make major runs up Nordhoff Ridge. Sundowner winds during their first few evenings drove both fires over the ridge and on into Ojai and Meiners Oaks. Here, however, the similarities begin to end. Where the 1948 Wheeler Springs fire spread rapidly to the east on its third day (similar to the major run of the 1932 Matilija fire), the 1985 Wheeler fire was pushed just as strongly up Matilija Canyon to the west. Also, though both fires came under a strong coastal influence on their third evening, the Wheeler fire had spread far enough inland to continue active burning. It is, however, interesting to note that both fires failed (at least temporarily) to burn across Dry Lakes Ridge, a feature that might be kept in mind in future suppression planning.



1948



1985

	TIME	ACREAGE
Wheeler Springs fire:	+27 hrs	11,275
Wheeler fire:	+24 hrs	7,310

	TIME	ACREAGE
Wheeler Springs fire:	+51 hrs	25,885
Wheeler fire:	+43 hrs	30,410

Figure 8. Comparative rates of spread between the 1948 Wheeler Springs fire and the 1985 Wheeler fire.

Scale: 1" = 4.35 miles. ●: Fire Origin

Two major factors probably contributed to preventing the Wheeler Springs fire from attaining the size of the Wheeler fire. First, a major effort was made to keep the fire north and east of Matilija Dam. Though a few spot fires did cross the road below the dam, there was apparently no major push in that direction as there was during the Wheeler fire. Had there been, the Wheeler Springs fire may have doubled or tripled in size. Secondly, when the coastal influence finally invaded the area of the fires, the Wheeler fire had grown to twice the size of the 1948 Wheeler Springs fire and had nearly three times as much open line. Complete control took longer to attain and exposed the Wheeler fire to further periods of critical weather. Still, these two fires were uncannily alike, burning over such of the same area and sharing much of the same perimeter.

The 1971 Romero fire. The Romero fire began at 1545 on October 6, on the second day of a severe Santa Ana condition. Weather conditions at the time of the fire were extreme, with temperatures of 100° or above and humidities below 10 percent all along the coast. Winds were erratic. The fire originated in Romero Canyon, on the coast side of the Santa Ynez Mountains, at an elevation of about 1000 feet (Figure 9). The cause of the fire was unknown, though assumed to be arson. By 1610, when the first forces arrived, the fire was estimated to be 25-40 acres in extent. Because of the severe conditions little direct attack was made on the fire and most initial efforts were concentrated upon keeping the fire south of the Camino Cielo fuelbreak. By 1800, driven by low humidities and erratic winds coming over the front ranges, the fire had grown to 450 acres, spreading to the north (upslope) and to the east. Shortly after 1800, the fire began spreadly rapidly downslope on a wide front, pushed by unforeseen and extreme sundowner winds. The fire consumed four houses and burned through Toro and Oil canyons during the night. By 0600 on the 7th, the fire had grown to 3600 acres.

By the morning of October 7, the Santa Ana condition had weakened considerably. Control efforts along the west flank of the fire progressed, and fire behavior was moderate as the marine layer began to re-infiltrate the area. By 1800, the fire had only grown to 4150 acres. At about 2100 the sundowner winds commenced with unexpected force. The entire southeast flank of the fire came alive, roaring toward Santa Monica Canyon. It was during this advance that one tractor operator and three Forest Service tractor bosses were overtaken by the fire front and killed. By 0600 on October 8, the fire had grown to 5150 acres and was beginning to threaten Carpenteria.

By then, however, the Santa Ana had completely broken down and, with the cessation of the sundowners, the marine layer had deepened. The high temperature in Santa Barbara on the 8th was 72°. Despite this, work on the east flank of the fire went slowly due to the steepness of the terrain. By 1800, fire had only consumed an additional 150 acres. This night, the sundowner winds

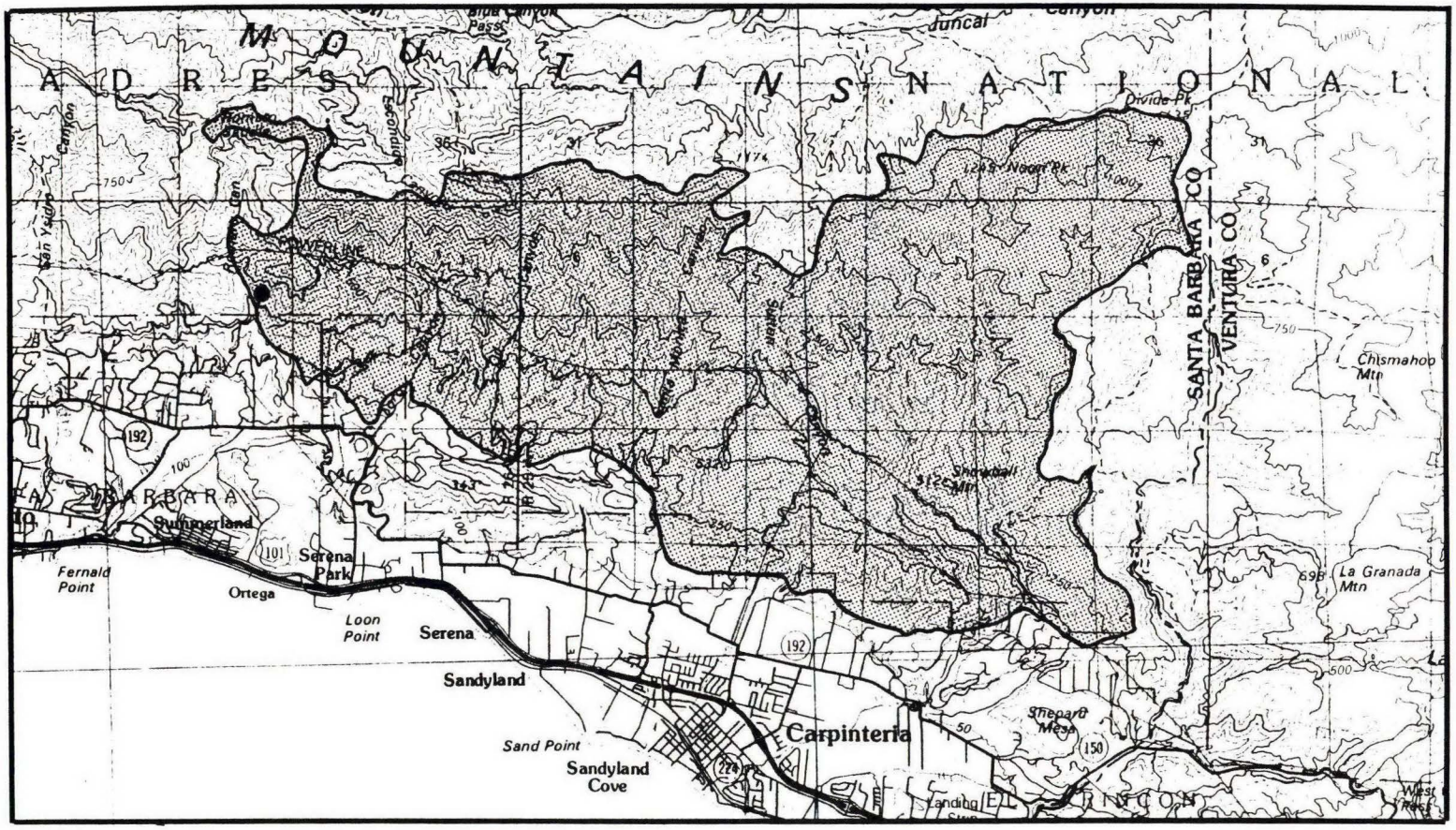


Figure 9. The 1971 Romero fire.

Scale: 1" = 1.58 miles. ●: Fire Origin

did not develop, though the fire still burned more actively than during the day, growing to 5800 acres by sunrise.

The day of October 9 again saw moderate burning conditions and progress was made on all parts of the line. At about 1930, however, the sundowner winds set in once again, forcing the evacuation of crews from the fire line. During the fifteen minute period from 1930 to 1945, the temperature at the fire camp rose from 62^{o} to 92^{o} and the humidity dropped from 68 percent to 16 percent (Ryan 1977). The fire front advanced rapidly toward the outskirts of Carpenteria. By 0600 on the 10th, the fire had consumed another 3000 acres, to a total of about 9000 acres.

By the day of October 10, another weak Santa Ana condition had become established and the east flank of the fire continued its rapid spread, consuming 3400 acres by nightfall. The night of the 10th did not see a return of the sundowner winds and the fire began to wind down, standing at about 13,000 acres at sunrise.

By the morning of the 11th, the high pressure behind the Santa Ana had begun to move east and a cooling trend set in throughout the fire area. Burning out operations began from the Camino Cielo fuelbreak south down the Rincon fuelbreak with the intent of preventing the fire from moving into the Santa Ynez watershed. Moderate burning conditions continued for the duration of the fire, hampering burning out operations along the Rincon fuelbreak to a certain extent. High temperatures in Santa Barbara dropped into the mid 60's and a dense marine layer dominated the area. The fire was declared contained at 0530 on October 13, and controlled at 1800 on the 16th. In all, the Romero fire blacked 14,528 acres.

The severe and recurrent sundowner winds that pushed the fire toward the populated coast were the most dramatic characteristic of the Romero fire. The severe Santa Ana conditions during the first days of the fire contributed to the fire's erratic behavior. Interestingly, the Romero fire spread primarily to the east. With the Santa Ana winds, coming out of the north or northeast, one would have expected the fire to spread in the opposite direction. However, the Romero fire occurred on the lee (south) side of the mountains, where the Santa Ana winds were rarely felt directly. Rather, the wind passing over the ridge crest probably drew air upslope beneath it (Ryan 1969). Terrain was also a major factor in the spread of the Romero fire. Even though there were a number of days of moderate burning conditions, the steepness of the mountain slopes prevented quick construction of control lines.

Of all of the fires reviewed in this section, the Romero fire was the most unlike the 1985 Wheeler fire, despite the sundowner winds. The fact that the fire occurred under Santa Ana conditions (the only large fire in the area to do so) and was confined entirely to the coast side of the mountains are major contributing factors to this difference.

The 1983 Matilija burn. The Matilija burn (Figure 10) began on July 7, 1983 as a prescribed fire conducted by Ventura County on the slopes on the south side of Matilija Canyon above Matilija Reservoir. Fuels were primarily mixed chaparral which had last burned in 1932. Though the burn was begun toward the hot end of the prescription, general weather conditions originally gave no indication of the escape to come. The presence of a surface level thermal low in the interior deserts combined with a strong upper level low in the Pacific Northwest appeared to guarantee a fairly stable onshore flow of marine air. The high temperatures on July 7th were 87° at Ojai and 77° at Santa Barbara. The day of the 8th saw little activity on the fire, and apparently the marine influence had strengthened some, at least along the immediate coast, as the temperature spread at Santa Barbara decreased from 19° on July 7th to 10° on the 8th.

However, conditions began to change early in the morning of July 9th. The District FMO was notified at 0530 hours that the expected upcanyon (NE) winds had suddenly changed to downcanyon (NW). Wind speeds were reported at 8-10 mph in the canyon bottom and 25 mph along the ridges. More important, the upper level low in northern California was beginning to weaken and high pressure was becoming established over the entire southwest. As the fire began to spread upslope along an open line, Forest Service and Ventura County forces began to prepare for the worst. At 1300 hours the Matilija burn was declared an escape and a Class I Fire Team was ordered. At this point, the fire was about 400 acres in extent, burning actively to the southeast toward Camino Cielo ridge, pushed by the down canyon winds. By midnight about 1500 acres had been consumed, and over six miles of line remained open. High temperatures on July 9th were 90° in Ojai and 80° in Santa Barbara.

By the morning of the 10th, high pressure aloft had become firmly established over the entire southwest United States, a typical "heatwave" weather condition. High temperatures soared to 101° at Ojai and 95° at Santa Barbara. Humidities hovered around 25 percent. Most of the line remained open, and the fire burned over Camino Cielo ridge to the coast side of the mountains. By midnight, the fire was estimated at about 3300 acres.

Weather conditions remained fairly stable with highs in the upper 90s for the next four days. However, the erratic winds began dying down on the 11th and the southern front of the fire slowed its progress as it backed into Santa Ana Canyon. Burning out operations began in the base of Matilija Canyon on July 13th.

By the morning of July 15th, the upper level high had weakened and the marine layer, accompanied by fog, became strongly established on the coast side of the mountains. Infrared imagery indicated the much of the southern perimeter of the fire was now cold. High temperatures on the 15th were 88° at Ojai and 74° at Santa Barbara. The cooling trend continued on the 16th and the fire was declared controlled at 1800 hours at 4600 acres.

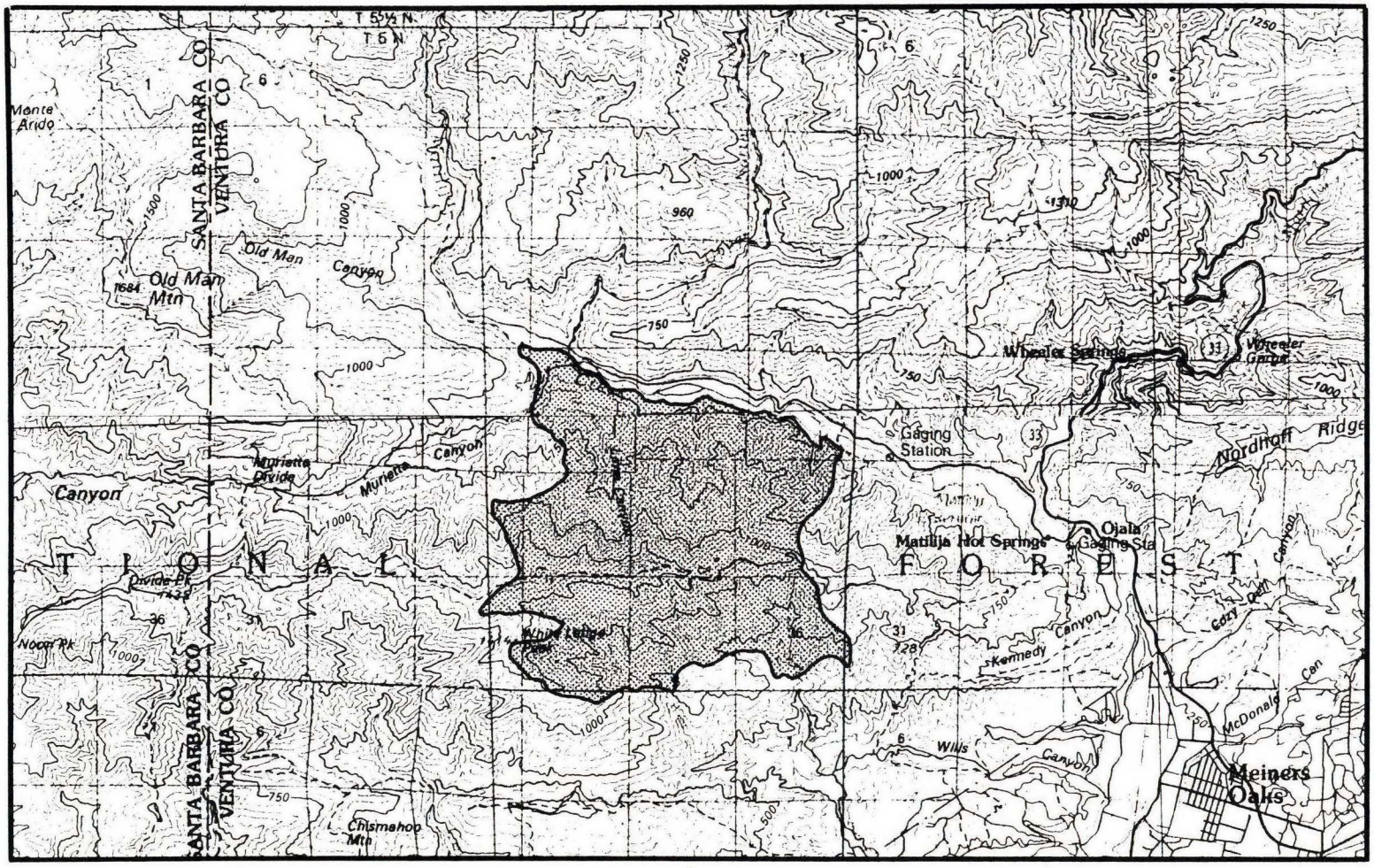


Figure 10. The 1983 matilija burn.

Scale: 1" = 1.58 miles.

The overall weather patterns present during the Matilija burn were very similar to those of the Wheeler fire. The establishment of the upper level high with its characteristic high temperatures and low humidities along with erratic winds were primary factors in the fire's spread. And as with the Wheeler fire, the eventual influx of the marine layer as the high weakened spelled the end of fire activity on the coastal side of the mountains. That the Matilija burn did not attain the size of the Wheeler fire can perhaps be attributed to three things: 1) the fire's proximity to the coastal influence; 2) the short duration and relative mildness of the heatwave condition; and 3) the lack of severe sundowner winds. The fact that fire fighting forces were prepared for the predicted escape probably also contributed somewhat to limiting the fire's spread.

Prefire Conditions

Having discussed the general background environment within which the Wheeler fire occurred, it is necessary to focus a little closer and examine certain conditions as they existed immediately prior to the fire. The following sections discuss factors contributing to high fuel flammability and suppression problems; factors having a large influence on the final extent of the Wheeler fire.

Rainfall and fuel age trends

One question of perpetual perplexity to fire managers is why there are large fires everywhere one year, while the previous ten had all been quiet. The answer, most will say, has to do with a combination of weather, fuels and ignitions. But in what way? Are there particular conditions of fuels and weather that favor large fires only once every ten or fifteen years? And if so, what is their nature and when do they occur? Work initiated in 1985 for San Diego County has begun to address this question by looking at the relationships between large-scale fuel age trends, rainfall patterns and the occurrence of large fires (Dunn 1987).

In researching the fire history of San Diego County, it was discovered that the most severe fire years appeared to be periodic in nature and seemed to follow a particular set of circumstances. Of the three worst fire years in the county's history, all occurred under strikingly similar conditions where levels of young fuels (i.e., less than ten years old) had dropped below a critical level. And though weather conditions varied somewhat, a loose correlation with precipitation emerged (Dunn 1987), with the worst fires occurring in drought years following one or more wet years.

The rationale behind the observed patterns is based primarily upon live fuel moisture relationships. The wet/dry

rainfall pattern appears to affect the chaparral in the following way: during wet year(s), the brush may exhibit above average growth levels. In the following drought year, the brush becomes stressed; perhaps some die-off occurs or the overall live fuel moisture drops as the plant tries to supply water to the newer biomass. In any case, the final result appears to be widespread and critically low live fuel moisture levels, highly conducive to sustaining large fires. Other mechanisms may also operate. For example, the stressed plants may contain higher levels of volatile compounds as a defense against herbivory. These compounds may significantly add to the flammability of the fuel.

Applying the same techniques to the Wheeler fire area yielded similar results (including a forecast of extremely severe fire conditions for 1985), re-enforcing the potential value of large-scale fuel and rainfall analysis for evaluating and predicting years with high potential for large fires.

The method of analysis is actually quite simple. Using fire records for the main division of the Los Padres National Forest (about 1.6 million acres, including the Ojai, Santa Barbara, Mt. Pinos and Santa Lucia districts), a table of annual acreage burned was created (Table 5). From this, a cumulative table of the percent of fuels in various age class groups was prepared for the main division of the Los Padres. By adding the acreage (or percentage) burned in the last ten years, the level of fuels less than ten years old was obtained (Table 5). This method works fairly well for fuels up to about fifteen years old, after which, a significant area may begin to experience reburning and age class acreage totals may show significant errors. Older age classes also appear to play a much smaller role in large fire occurrence than the <10 year class (Dunn 1987), so they were not included in the present analysis. Precipitation data for Santa Barbara (Fritz Cahill, pers. comm.) was included to fill out the analysis (Figure 11). The annual rainfall totals, with an annual mean of 17.38 inches, were converted to percent of normal (Table 5).

As was the case for San Diego County, periods with low levels of young fuels (or, conversely, high levels of older fuels), were always followed by severe fire years, generally during drought years following one or more wet years. Bad fire years in 1964 and 1966 occurred under exactly these conditions (Table 5). In 1977, young fuel levels dropped below 4 percent and continued to drop to below 2.0 percent. By 1983, fully 98.5 percent of all fuels on the main division of the Los Padres were greater than ten years old; a level never even approximated in San Diego County. But there were no major fires. Why? This apparently unnatural situation can be attributed to the long string of wet years that began in 1978 and continued through 1983 (Table 5). Rainfall during this six year period <u>averaged</u> 160 percent of normal, raising live fuel moistures and suppressing any tendency for large fires to occur.

Table 5. Precipitation, acreage burned and level of less than ten year old fuels for the main division of the Los Padres National Forest, 1950-1985. (Source: Data on file, Los Padres National Forest, Goleta, CA.)

MAIN DIVISION, LOS PADRES NF: 1,600,000 acres

YEAR	RAINFALL % NORM	ACREAGE BURNED	PERCENT OF AREA BURNED	PERCENT OF FUELS <10 YR
1950	62.60	33823	2.11	
1951	58.86	21003	1.31	
1952	171.58	49	.00	
1953	55.81	31111	1.94	
1954	89.93	837	.05	
1955	96.43	55859	3.49	
1956	94.71	3202	.20	
1957	89.64	19167	1.20	
1958	223.42	311	.02	
1959	48.45	632	.04	
1960	67.66	12715	.79	10.36
1961	38.20	2982	.19	9.04
1962	137.64	68	.00	7.92
1963	129.92	1727	.11	7.92
1964	57.94	64051	4.00	6.09
1965	131.47	816	.05	10.04
1966	45.91	97599	6.10	6.60
1967	140.33	3223	.20	12.50
1968	87.17	3638	.23	11.50
1969	134.64	449	.03	11.71
1970	67.38	2200	.14	11.70
1971	67.49	18956	1.18	11.05
1972	42.06	17284	1.08	12.04
1973	116.00	174	.01	13.12
1974	92.06	475	.03	13.02
1975	108.69	3703	.23	9.05
1976	63.81	677	.04	9.23
1977	89.70	2115	.13	3.17
1978	265.77	1128	.07	3.10
1979	132.68	3135	.20	2.94
1980	134.87	6887	.43	3.11
1981	109.49	894	.06	3.40
1982	116.74	867	.05	2.28
1983	215.25	4929	.31	1.25
1984	48.27	2566	.16	1.55
1985	60.13	165411	10.34	1.68
1986	144.53	--	--	11.79

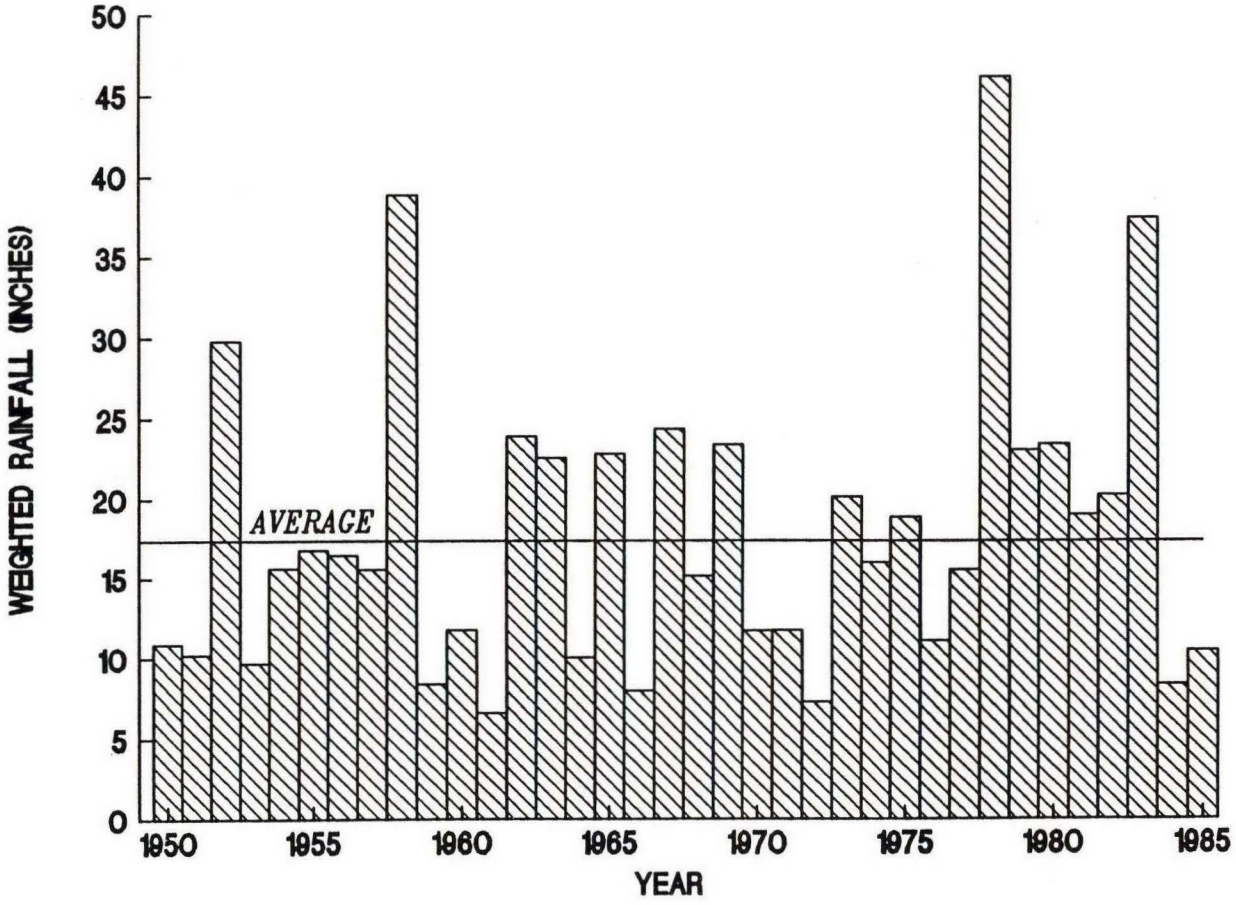


Figure 11. Total annual rainfall in Santa Barbara, 1950-1985.

SOURCE: Data on file, Los Padres National Forest, Goleta.

By 1984, conditions were apparently set (according to the model) for a severe fire year. But even though 1984 was a severe drought year and summer temperatures in the area averaged two to four degrees above normal, no large fires occurred, pointing out the need for further research in this area.

Whatever was the case in 1984, 1985 presented almost identically severe conditions. Over 98 percent of the fuels in the main division of the Los Padres were greater than ten years old and had been at critical levels since at least 1977. The long series of wet years had ended in 1983 and the winter of 1984-85 brought only 60 percent of normal rainfall to the area. At Wheeler Springs in June 1985, only 0.83" of rain had fallen since Christmas, over six months earlier, and no rain had fallen for nearly three months. Live fuel moistures in the area, measured in mid-June, stood at 62 percent--nearly 20 percent below normal for that time of year. The fuels in Wheeler fire area were in critical condition and needed only the concurrence of severe fire weather and an ignition to support a conflagration.

State-wide Fire Situation as of July 1, 1985

With the dry conditions and low fuel moistures, fire fighting organizations prepared for the possibility of a severe season. Still, the weather during much of June gave no indication of what was to come. Low pressure dominated Southern California, and the dense marine layer kept temperatures in the 70's all along the coast. Conditions began to change during the last week of the month as upper level high pressure over the Pacific began to shift east toward the southern part of the state on June 26. The inland areas were the first to feel the change. As the marine influence weakened, the high temperature in Ojai jumped from 74° on the 25th to 101° on the 26th. By the 30th, high pressure was firmly established over the state and the marine layer had virtually disappeared, and temperatures in coastal locations soared into the 90's.

As the weather became severe toward the end of the month, large wildfires began errupting throughout Southern California. Though not the first, the Wheeler fire was to become the largest of the series of over a dozen large fires that broke out in the state between June 27 and July 7 (Table 6). The fires that began before the Wheeler fire drained forces from the forests, leaving many of the 'quiet' areas severely underprotected. This situation became even worse after the start of the Wheeler and Las Pilitas fires, when mere token forces were left on virtually every district of every forest in the state. At the height of the fires, 12,000 firefighters from around the country were fighting the blazes.

The first truly large fire of the 1985 fire season began at 1058 hours in the San Jacinto Mountains of Riverside County. The Cabazon fire spread rapidly to over 4000 acres, and with the

Table 6. List of major wildfires in Southern California, June 27-July 7, 1985. (Adapted from: U.S. Department of Agriculture 1985.)

FIRE	DATE START	ACREAGE	LOCATION
Cabazon	6/27	21,000	Riverside Co.
Richbar	6/28	9,223	Kern Co.
Lehr	6/30	600	San Diego Co.
Miller	6/30	8,000	San Diego Co.
Sherwood	6/30	3,820	Ventura Co.
Gopher	7/1	650	San Diego Co.
Las Pilitas	7/1	74,640	San Luis Obispo Co.
Roblar	7/1	8,425	San Diego Co.
WHEELER #2	7/1	107,828	Ventura Co.
Deer Springs	7/2	500	San Diego Co.
Green River	7/2	700	Orange Co.
Mammoth	7/2	580	Sierra NF
Black Mt.	7/3	1,025	Ventura Co.
Sierra	7/3	459	San Bernardino Co.
Seco	7/5	1,800	Monterey Co.
Gorda/Rat	7/6	56,039	Monterey Co.
Onion	7/7	9,800	Inyo Co.

severe weather conditions, South Zone committed forces from all over the state to this fire. (This was to have a potentially critical impact on the Wheeler fire. Of the three engines on the Ojai District of the Los Padres National Forest, two, including the Wheeler Springs engine, were sent to battle the Cabazon fire. The closest remaining Forest Service engine to the future origin of the Wheeler fire was stationed at Oak Flats, an hour and a quarter away.) By July 1, the fire had grown to over 20,000 acres and was only 50 percent contained. Meanwhile a number of other fires had sprung up throughout the state, further draining needed resources. Some crews, first sent to the Cabazon fire, would not return to station until over four weeks later.

The next fire to erupt, the Richbar fire, was on the Sequoia National Forest in Kern County. Starting at 1300 hours on June 28th, the fire quickly spread to over 5000 acres, but began to die down on the 29th. By 0600 hours on June 30th, the Richbar fire was declared controlled at 9,223 acres. Also on the 28th, a fire started in Wheeler Canyon north of Ojai. This fire was quickly suppressed at only 70 acres, raising questions concerning the factors that contribute to the escape or suppression of wildfires. Questions for which there are, as yet, few answers.

On the last day of June, fire starts began to increase throughout the southland. At 1147 hours the Miller fire began in light dry fuels in southern San Diego County. By July 1st, the fire had consumed 8,000 acres and was nearing complete containment. At nearly the same moment that the Miller fire began, a fire broke out in one of the canyons within the city of San Diego. The Lehr fire (usually referred to as the 'Normal Heights' fire) would quickly consume 600 acres and 47 homes, causing $9 million in property losses. The Sherwood fire, in Ventura County, also broke out on June 30th, burning 3,820 acres.

On July 1st, the fire situation worsened by several degrees, with the start of three major wildfires which would eventually blacken nearly 200,000 acres. The first of these would compete with the Wheeler fire for both forces and the attention of the public throughout the 15 days that it burned. The Las Pilitas fire began at about 1315 hours on CDF protection land in San Luis Obispo County. Within five hours of its origin, it had spread to over 1,000 acres. It would eventually cover 75,000 acres and burn up to the edge of the city of San Luis Obispo. The next major fire to start on July 1, at 1500 hours, was the Wheeler #2 fire. A little over an hour later, at 1617 hours, the Roblar fire started on Camp Pendelton in San Diego County, quickly spreading to over 1,000 acres. It was finally contained on July 5th at over 8,400 acres. Also on July 1st, the Gopher fire consumed 650 acres north of Escondido in San Diego County.

THE 1985 WHEELER FIRE

Approximately 95 percent of all wildfires in California burn less than 300 acres. Of the remaining fires, another 95 percent are stopped at under 10,000 acres (Dunn 1987). Of all of the tens of thousands of fires in the state since 1910, only seven are known to have exceeded 100,000 acres (Table 7). Though these seven fires alone have accounted for over 1,000,000 blackened acres and caused millions of dollars in property losses, none of them have previously been analyzed in any great detail.

When the Wheeler fire began on July 1, 1985 there was little indication that it would eventually consume nearly 108,000 acres, making it the fifth largest fire (at the time) in California history. But by the evening of July 3, it had already consumed 60,000 acres in the inaccessible mountains of Ventura County. From an arsonist's spark, the fire had grown into the largest blaze in the state in eight years. After it had been burning for about 60 hours, the Wheeler fire began to slow down (Figure 12). For the next few days, the fire advanced slowly, primarily in the interior areas. After one final burst of activity on July 8, the fire died down almost completely. From July 9 onward, the only real activity on the fire was from burning out operations. At 0600 on July 15, the Wheeler fire was declared controlled after blackening 107,828 acres. The following sections outline the career of the fire and discuss the various factors affecting its behavior.

Chronology of the Wheeler Fire

The Wheeler fire lasted 15 days, burned nearly 108,000 acres, had a final perimeter of 96 miles and was fought by over 3000 firefighters. While it burned many things were happening at different locations. Though a more detailed discussion of the fire will follow in later sections, this chronology condenses the major events of the fire into an outline format that gives a concise temporal overview of the fire. Numbers listed beneath the dates are the times of the listed events. Approximate times are given when the exact times of events are unclear or unknown.

July 1, 1985

1500 Origin of Wheeler Fire near Wheeler Hot Springs at T5N R23W Sec 22 NE1/4 of NW1/4. Apparent cause: arson. Fire origin on 80% slope with a southern exposure. Average live fuel moisture: 62%. Weather at Matilija Dam (2 miles south of origin) at 1500 hours: Temp: 104^{o} F; RH: 15%.

Table 7. Largest known fires in California, 1910-1987.

FIRE	DATE START	ACREAGE	COUNTY
Matilija	9-7-32	219,254	Ventura
Marble Cone	8-1-77	177,866	Monterey
Laguna	9-26-70	175,420	San Diego
Beauty Peak	9-18-28	167,000	Riverside/San Diego
Stanislaus Complex	8-30-87	145,980	Tuolumne
WHEELER #2	7-1-85	107,828	Ventura
Clampitt	9-27-70	107,163	Los Angeles

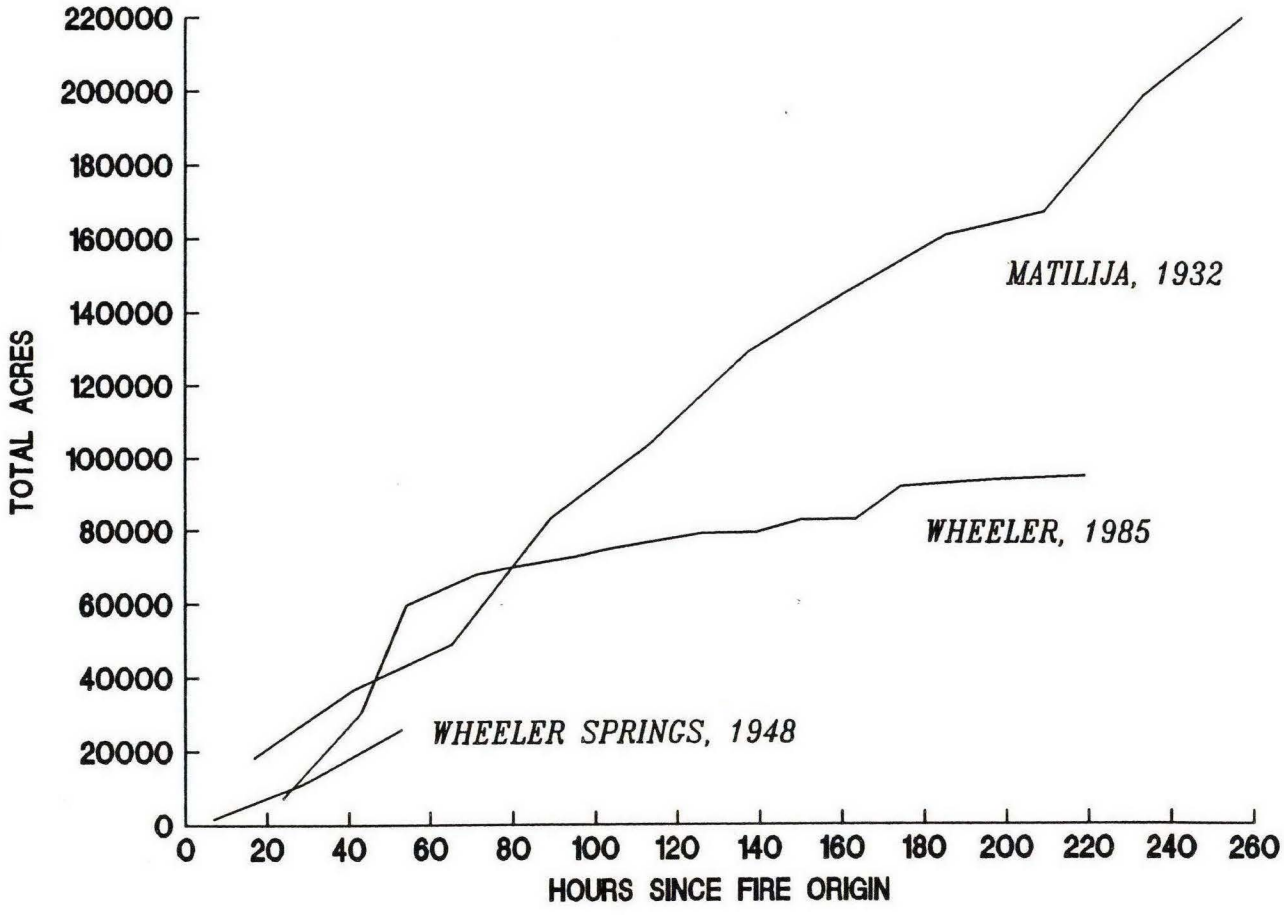


Figure 12. Rates of growth for the 1932 Matilija, 1948 Wheeler Springs and 1985 Wheeler fires. Note the rapid rate of growth in the first 60 hours of the Wheeler fire.

1515 First forces arrive at fire. Estimated size: 1-2 acres.

1530 Estimated size: 30 acres.

1545 (Approximate time) Fire spots across to south side of Highway 33. Evacuations begin in Wheeler Canyon; Highway 33 is closed.

July 2, 1985

0100 (Approximate time) Second fire spotted near base of Cozy Dell Canyon, burning upslope.

0230 (Approximate time) Second fire turns and begins to advance toward Ojai, pushed by sundowner winds. Sundowner winds continue sporadically until sunrise.

0400 (Approximate time) Evacuations begin along Foothill Road and at Camp Ramah.

0800 Class 1 team takes over fire.

1505 Time of U2 flyover. Fire burning actively to the NE from Dry Lakes Ridge south across Highway 33 to Nordhoff Peak. Secondary fire is just now joining the main burn at Nordhoff Ridge about a mile west of Nordhoff Peak. Current size: 7,310 acres (Figure 13).

1800 (Approximate time) Fire intensifies along southern front, advancing toward Ojai and Matilija Canyon. Sundowner winds again blowing erratically along front country; continue sporadically until sunrise.

1915 Wheeler fire crosses Matilija Canyon at Matilija Dam. Hygro-thermograph there records temperature of 117°.

2000 (Approximate time) Fire burning actively to the SW, entering Rice Canyon.

2200 (Approximate time) Burning out begins along Highway 150 north of Lake Casitas. Evacuations intensify at Ojai.

July 3, 1985

1000 (Approximate time) Wheeler fire begins its major run, spreading now primarily to the west, pushed by winds entering Matilija Canyon. Begins burning into and around the 1983 Matilija burn. Current size: 30,410 acres (Figure 14).

1200 (Approximate time) Burning out begins along Rose Valley Road.

1400 (Approximate time) Homeowners in Matilija Canyon light unauthorized backfires to protect their property. Witnesses say that this gives rise to the most severe behavior of the fire, as the fire front meets the backfires.

1540 Origin of the Black Mountain fire, south of Ojai. This fire would draw off some forces from the Wheeler fire and eventually consume 1,025 acres.

1800 (Approximate time) Sundowner winds begin again along fornt ranges.

2100 East front of fire front passes Thacher School in Ojai. Since 1000 hours the west front of the fire has burned a distance of seven miles, a rate of over 50 chains/hour. Current size: 59,490 acres (Figure 15).

July 4, 1985

0300 (Approximate time) End of sundowner winds. Marine influence enters front range area. End of the fire's major run to the west. Fog and high humidities will hamper burnout operations in the front range area for the duration of the fire. Burning out begins along Highway 33 west from Rose Valley Road.

1200 (Approximate time) Ventura County firefighters begin backfiring north from Laguna Ridge.

1400 Fire spreading actively primarily along northern fronts. Southwestern front of fire entirely inactive. Current size: 67,880 acres (Figure 16).

1800 Burning out begins unsuccessfully along Sisar Road.

2100 Fire activity limited to sections of northern front. Current size: 69,380 acres (Figure 17).

July 5, 1985

1400 Current size: 72,510 acres.

1800 Burning out begins unsuccessfully from Noon Peak west. Burning out operations begin on Monte Arido fuelbreak.

2100 Fire quiet on all but parts of the northern front. Current size: 74,590 acres (Figure 18).

July 6, 1985

1000 Current size: 76,800 acres.

2100 Fire inactive on all but small portions of the northern front. Current size: 78,870 acres (Figure 19).

July 7, 1985

0600 Firing continues in all areas with greater success today.

1000 Current size: 79,060 acres.

2100 Fire quiet on all but portions of the western and northern fronts. Current size: 82,140 acres (Figure 20).

July 8, 1985

1000 Current size: 82,560 acres.

1100 (Approximate time) Fire activity begins increasing on all fronts.

1400 High temperature in Ojai: 98^{O}; highest since July 3. RH: 31 percent.

2100 Fire makes major advances to the west north of Jameson Lake and to the east near Sisar Canyon. Fire advances to the south for the first time since July 3. Current size: 91,530 acres (Figure 21).

July 9, 1985

0200 Strong marine influence re-invades fire area; end of last major run.

2000 Fire mostly inactive on all but the northern front. Current size: 93,300 acres.

July 10, 1985

0000 Manpower assigned to the Wheeler fire reaches its highest level: 3,180 fire fighters and overhead.

1800 Fire completely inactive except for burning out operations on portions of the northern and southwestern fronts. The wildfire phase of the Wheeler fire ends. Current size: 94,330 acres.

July 15, 1985

0600 Wheeler fire declared controlled. Official acreage stands at 118,000 acres (107,828 acres actual; Figure 22). Cost of suppression: $9 million.

Weather as a Fire Behavior Factor

Weather has long been recognized as a major factor in fire behavior, and the least controllable. Though fuel breaks can be cut and aspects of terrain exploited, nothing can be done to make the weather cooperate in fire suppression. Further, fuels and terrain are solid, visible and immovable, while the weather, constantly in motion, is something that usually has to be measured rather than seen directly. As the least controllable and least visible element affecting fire behavior, it demands the greatest level of understanding. Sudden unexpected changes in weather can give rise to dramatic changes in fire behavior. Indeed, the majority of fire fatalities can be traced to changes in fire behavior due to unpredicted changes in weather conditions. Furthermore, most truly large fires are "weather driven," that is, weather appears to be main factor influencing the spread of the fire. Narrative accounts of the major wildfires in this country, from the Idaho fires in 1910 and the Tillamook fire of 1933 to the Laguna fire of 1970, all pretty much end with: "But it was not until the weather changed that the fire could finally be brought under control." The Wheeler fire was no different. Severe burning periods coincided with severe weather periods, and the fire remained uncontrollable until weather conditions moderated.

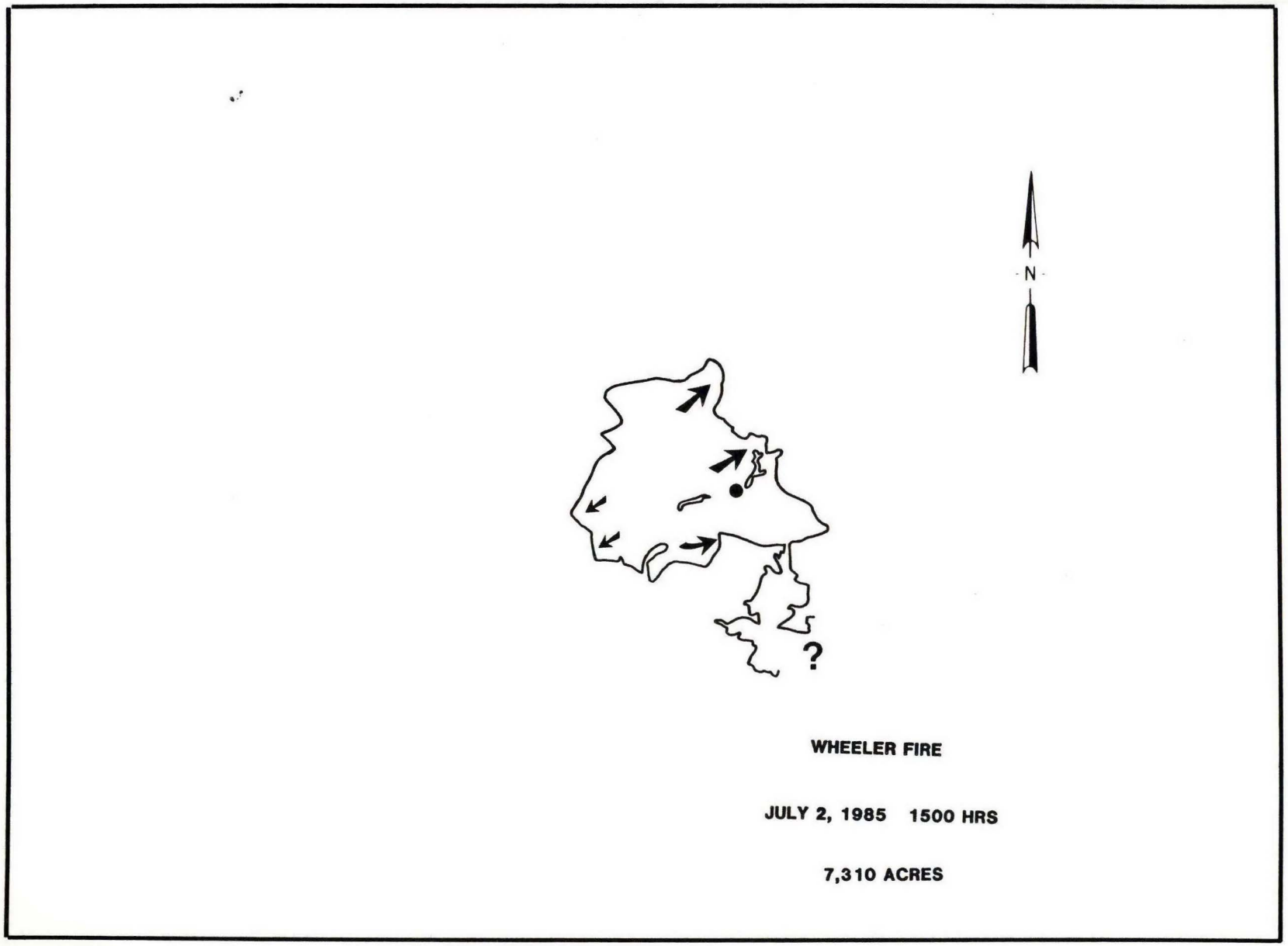


Figure 13. Extent of the Wheeler fire, 1500 hours, July 2, 1985.

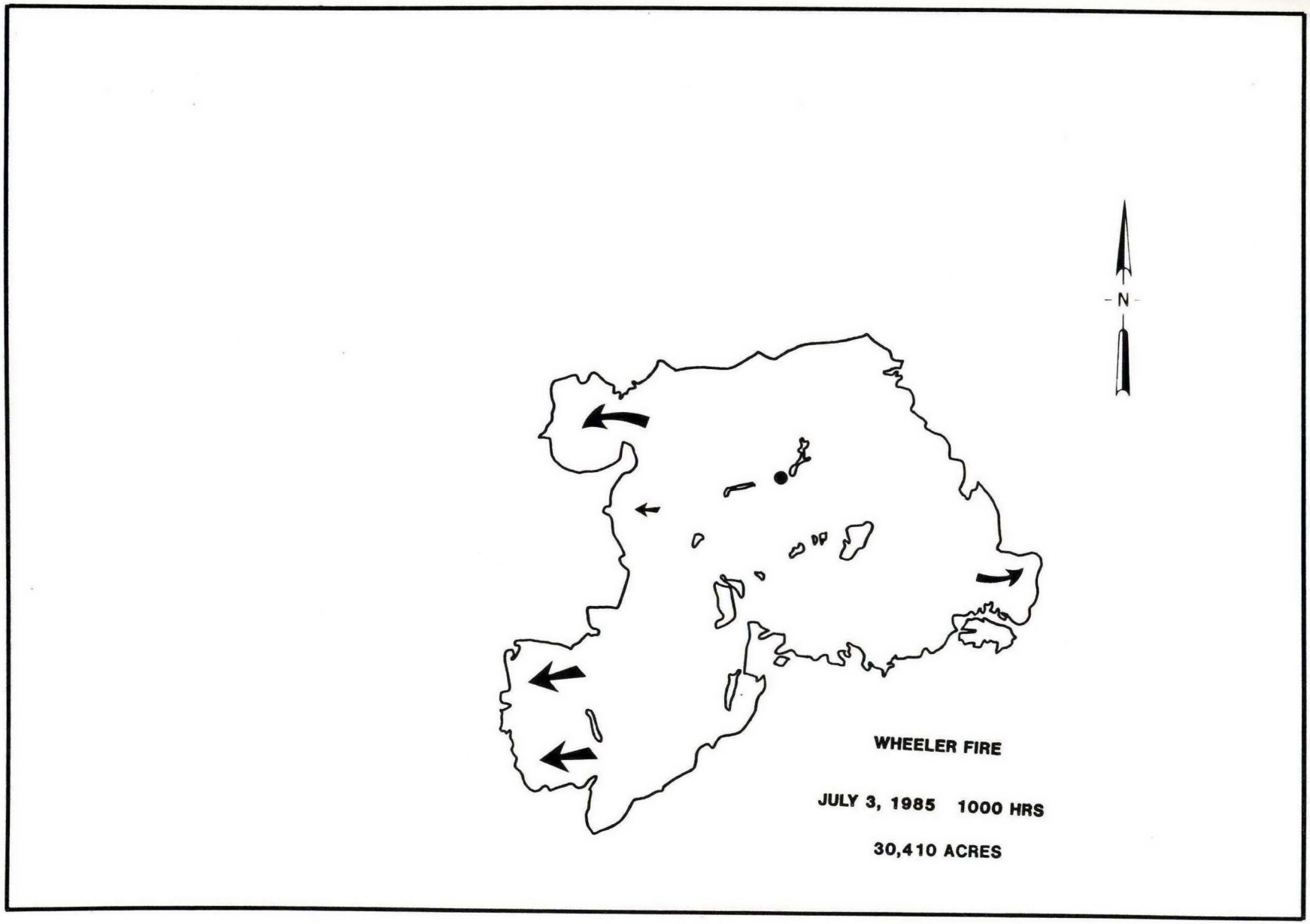


Figure 14. Extent of the Wheeler fire, 1000 hours, July 3, 1985.

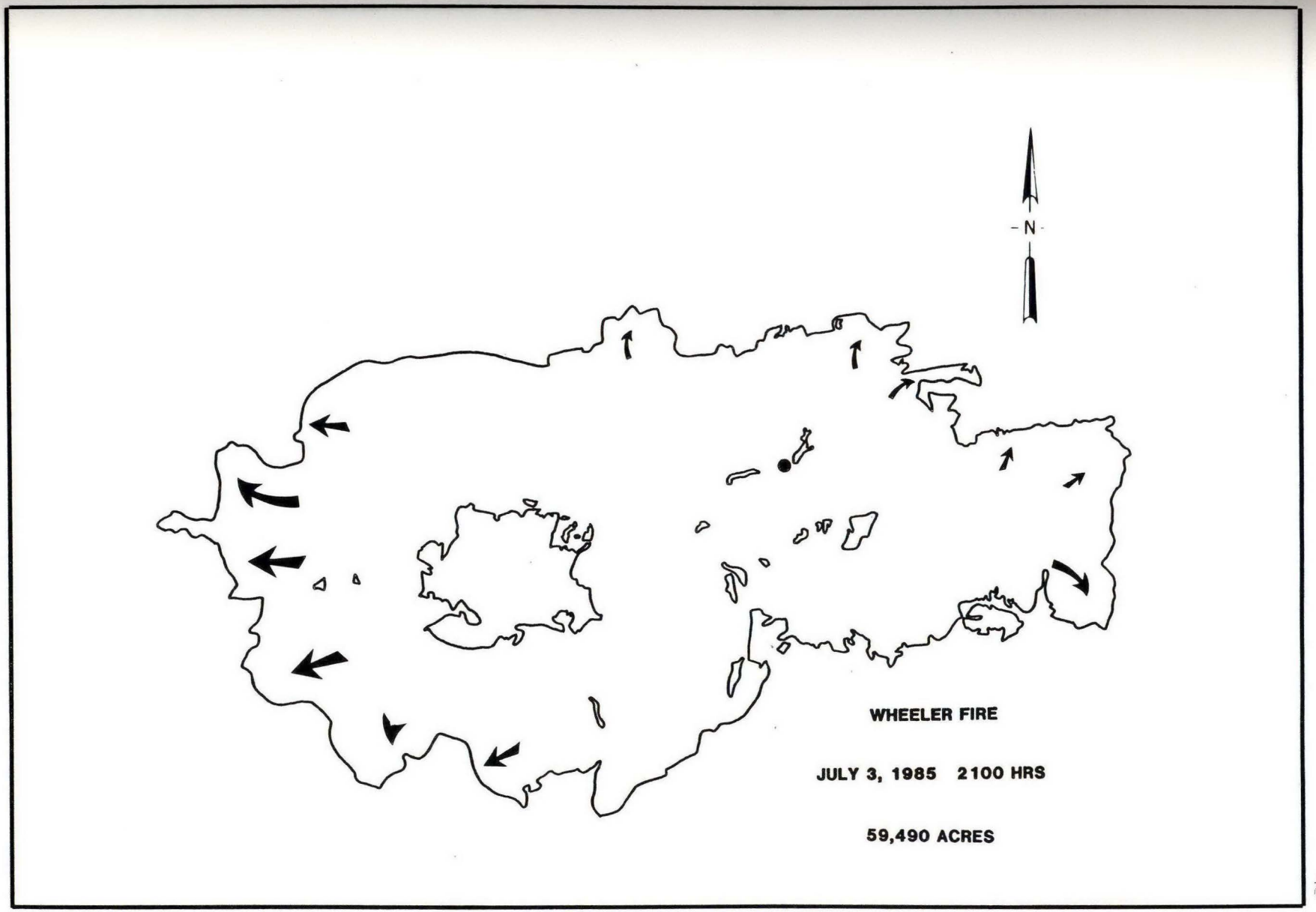


Figure 15. Extent of the Wheeler fire, 2100 hours, July 3, 1985.

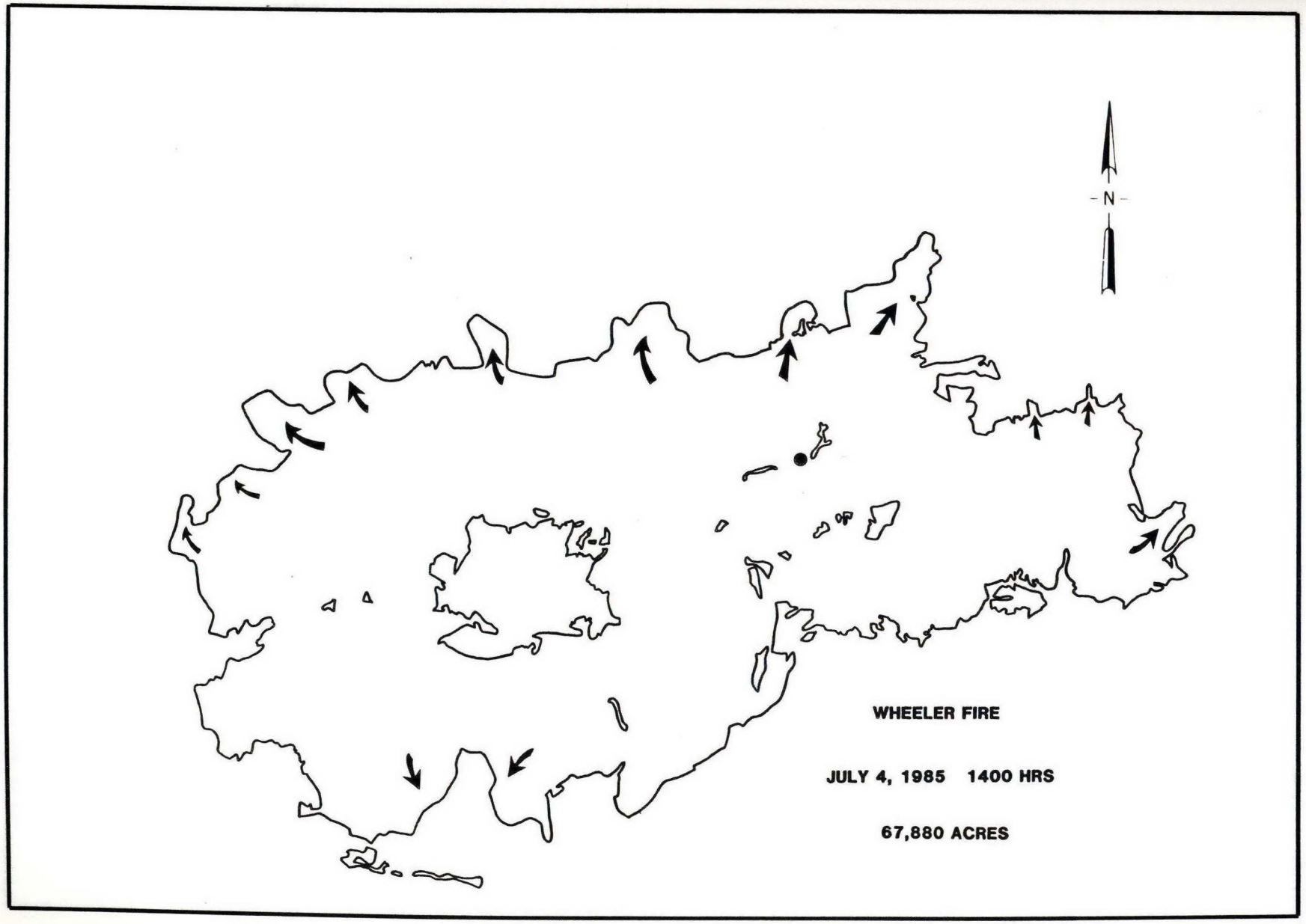


Figure 16. Extent of the Wheeler fire, 1400 hours, July 4, 1985.

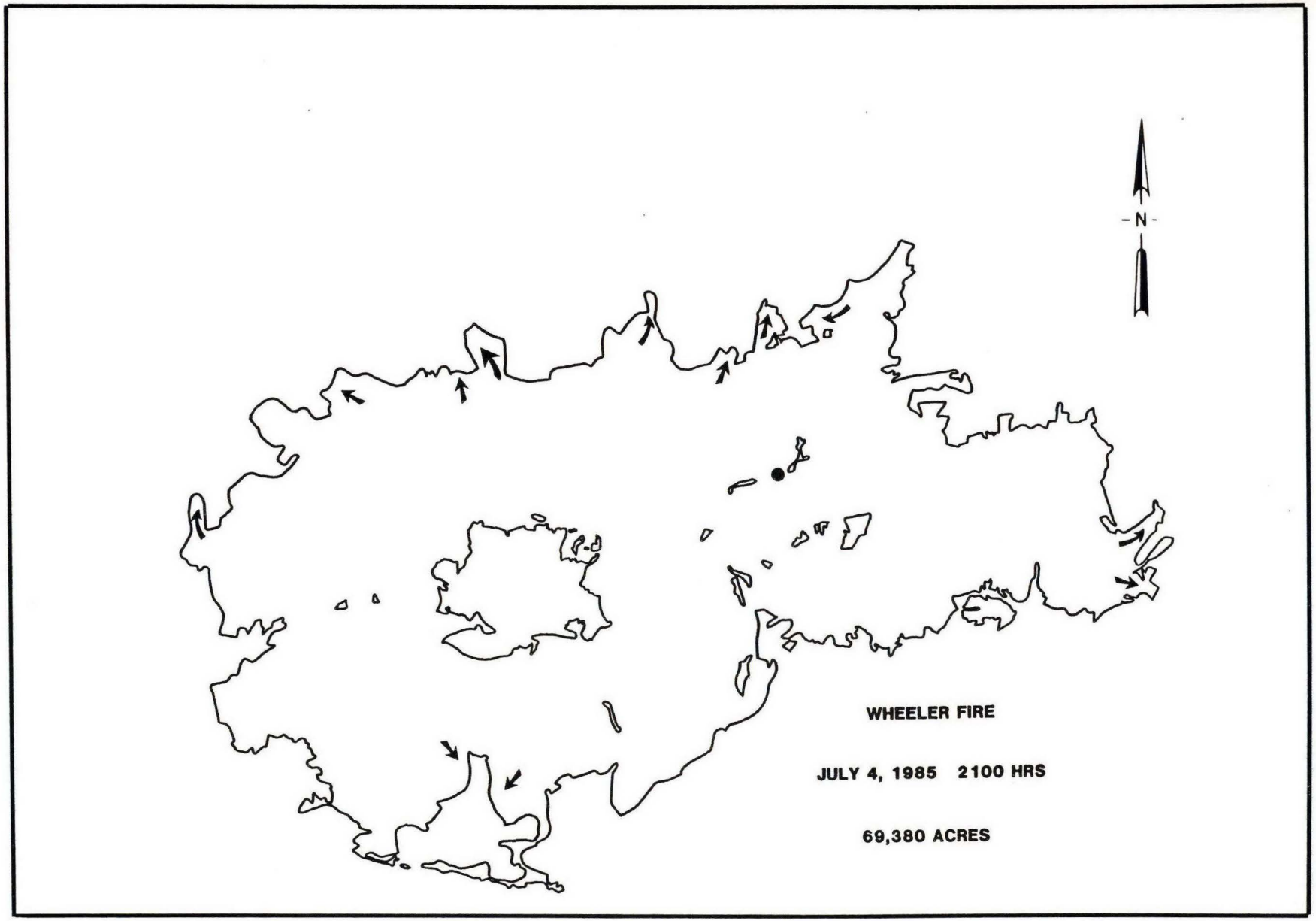


Figure 17. Extent of the Wheeler fire, 2100 hours, July 4, 1985.

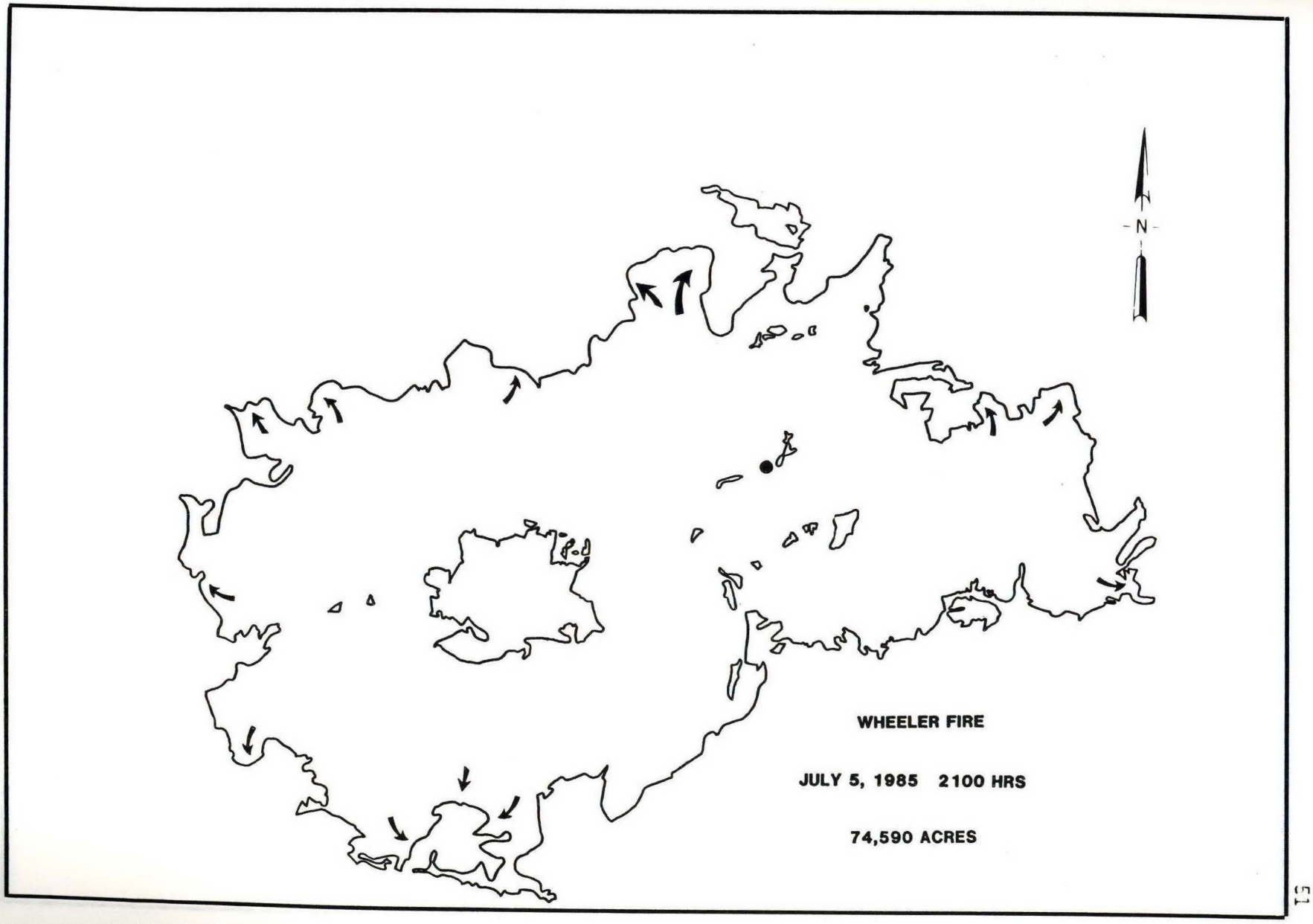


Figure 18. Extent of the Wheeler fire, 2100 hours, July 5, 1985.

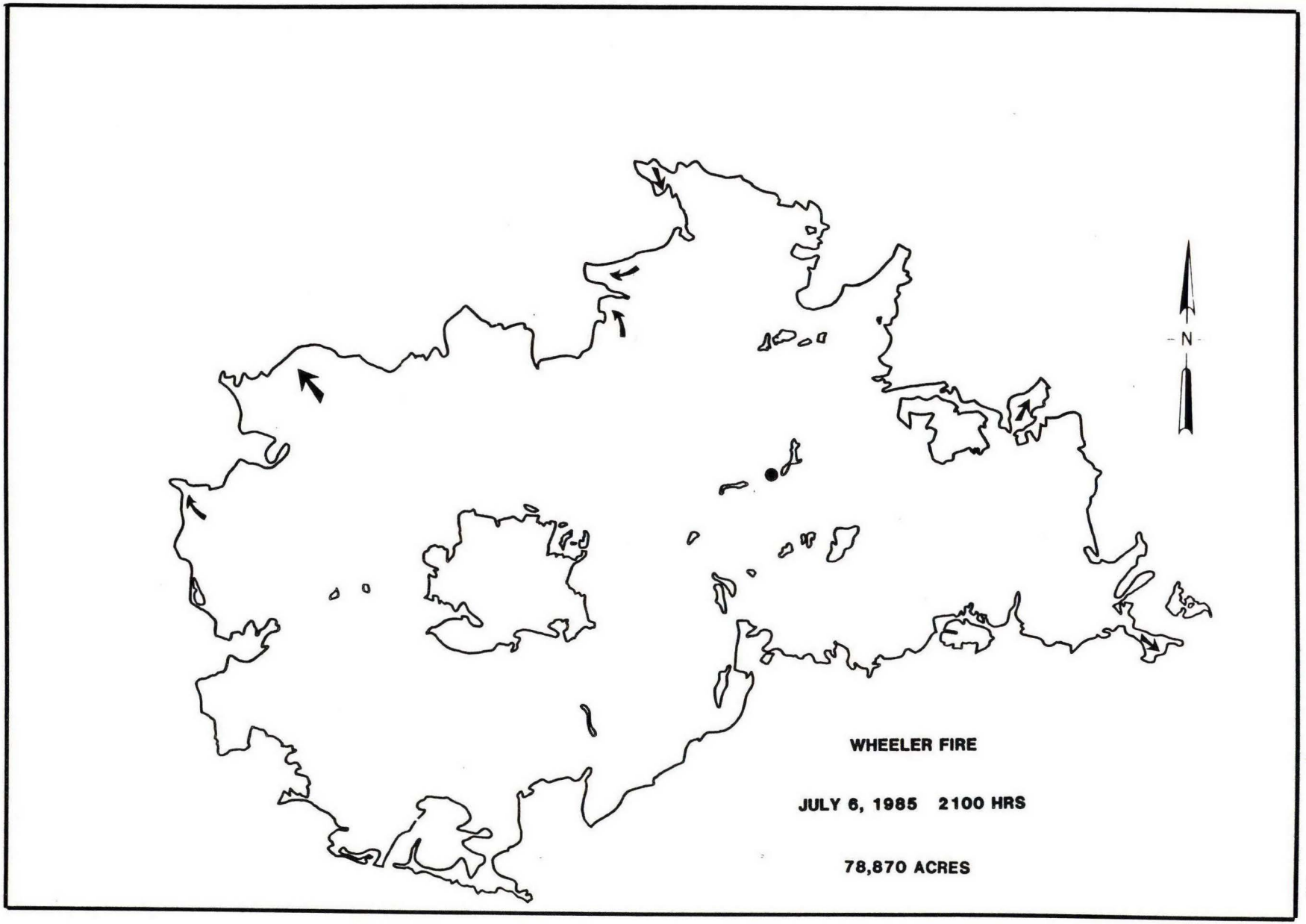


Figure 19. Extent of the Wheeler fire, 2100 hours, July 6, 1985.

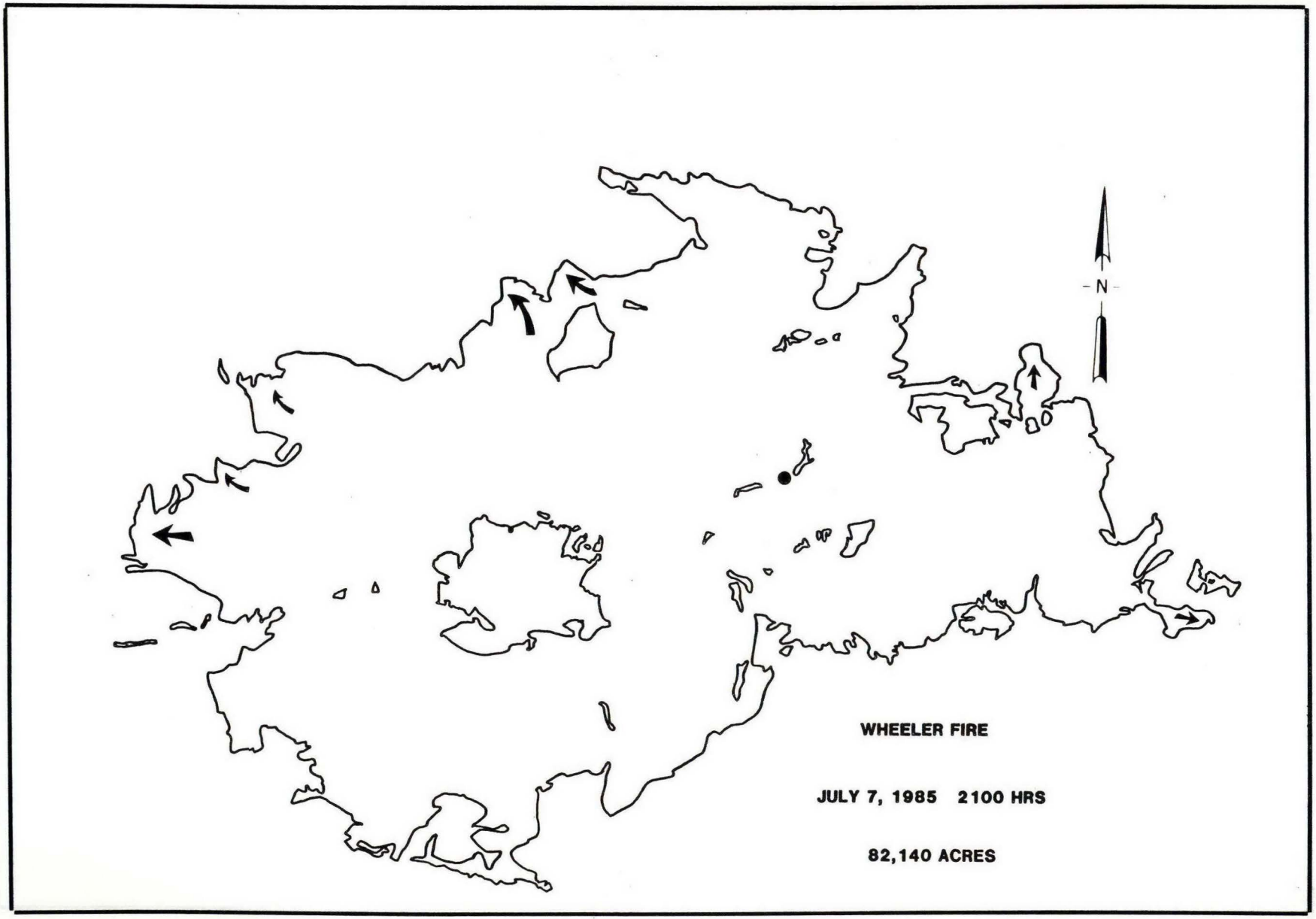


Figure 20. Extent of the Wheeler fire, 2100 hours, July 7, 1985.

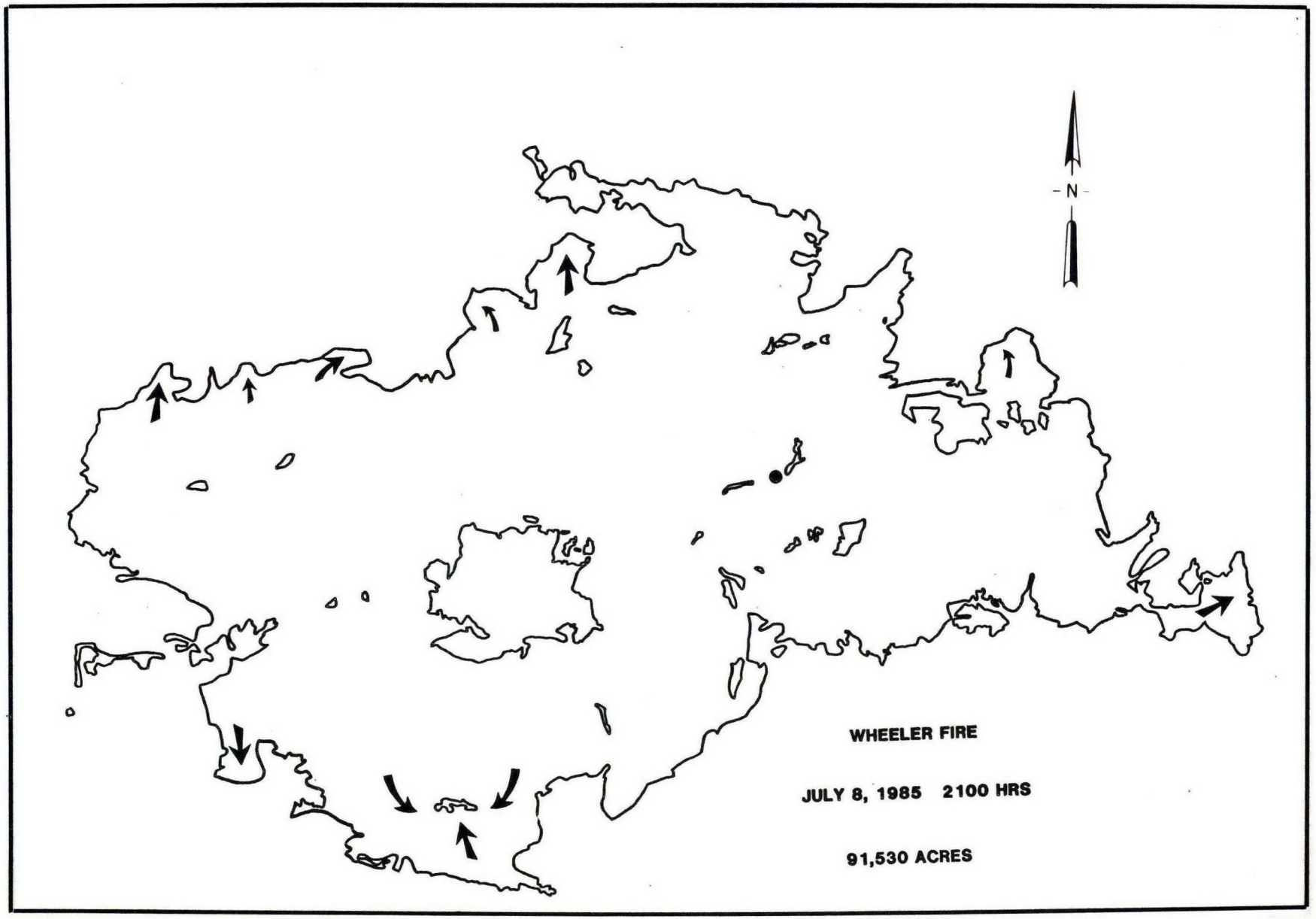


Figure 21. Extent of the Wheeler fire, 2100 hours, July 8, 1985.

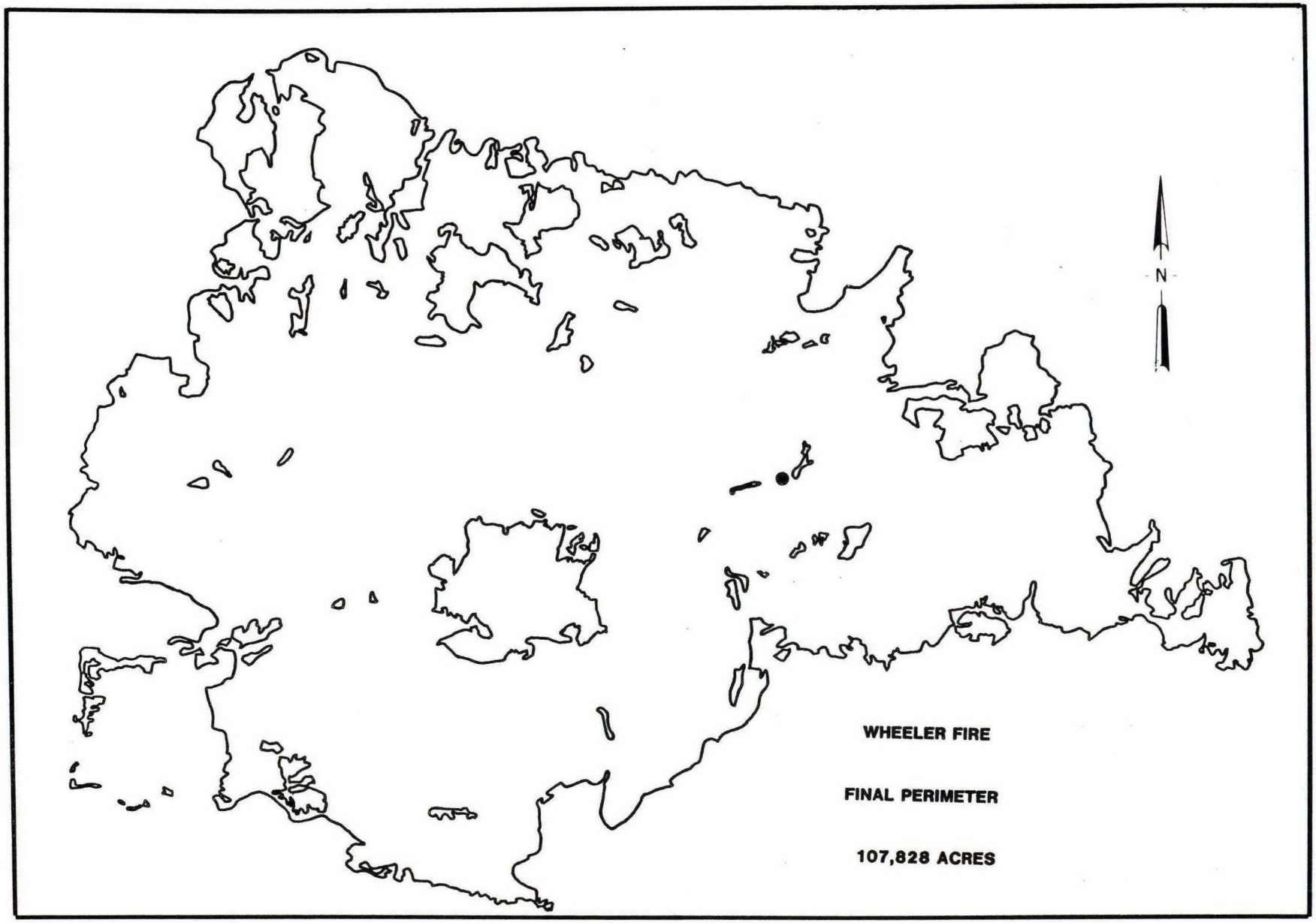


Figure 22. Final perimeter of the Wheeler fire. Total area, including islands: 116,904 acres. Area burned: 107,828 acres.

In order to gain any understanding of the Wheeler fire, therefore, we must attempt to understand the weather that drove it.

The subtropical high aloft condition

Like a number of historical fires in the area, the Wheeler fire occurred under a subtropical high aloft or "heatwave" weather condition (Schroeder and others 1964). Under this weather type, an upper level high pressure system of warm, dry air becomes established over the western United States (Figure 23). This upper level high is fairly common during the summer months (Figure 24), blocking the movement of cooler and moister air masses into the area. The subtropical high aloft is also a very stagnent air mass, sometimes remaining in place for weeks. Temperatures often soar into the 100's; thus the name "heatwave." Due to its stagnent nature, there is very little in the way of large scale wind movements under the upper level high condition. Most winds are local and topographic in nature, being generated by differential heating of mountain slopes. The high temperatures often generate a thermal low on the surface (Figure 25), as the heated air rises convectionally. This often intensifies the onshore flow of marine air, but in cases where the upper level high particularly intense, the onshore flow may actually weaken as the air offshore is heated.

The subtropical high aloft under which the Wheeler fire occurred began to move into the area during the last days of June. By the morning of July 1, the high had become firmly established over Southern California (Figure 26). At the time that the Wheeler fire began (about 1500), the temperature at Matilija Dam stood at 104^{O} and the relative humidity was 15 percent. For the next two and a half days the pressure remained extremely high (Figure 26). The usual onshore flow weakened and the high temperature at Santa Barbara soared to 109^{O} on July 2. Relative humidities, both along the coast and inland remained unusually low (Table 8), hovering around 20 percent at Matilija Dam for the first three days of the fire (Figure 27).

Beginning on the night of July 3, the upper level high began to weaken (Figure 26) as did the thermal low (Figure 25). This weakening allowed an influx of moist marine air, first noticable at Santa Barbara late on the night of the 3rd and at Matilija Dam by the afternoon of July 4 (Figure 27; Table 8). The somewhat weakened upper level high remained in place for the next few days, but the marine layer had become firmly established along the coast and penetrated inland during the evening. High temperatures dropped by as much as 30 degrees (Table 9), and remained moderate until July 8. On the day of the 8th, the high strengthened slightly (Figure 26), resulting in an increase in temperature and a marked drop in relative humidities (Table 9; Figure 27). But by the evening of July 9, humidities had again begun to rise and the upper level high started to drift east.

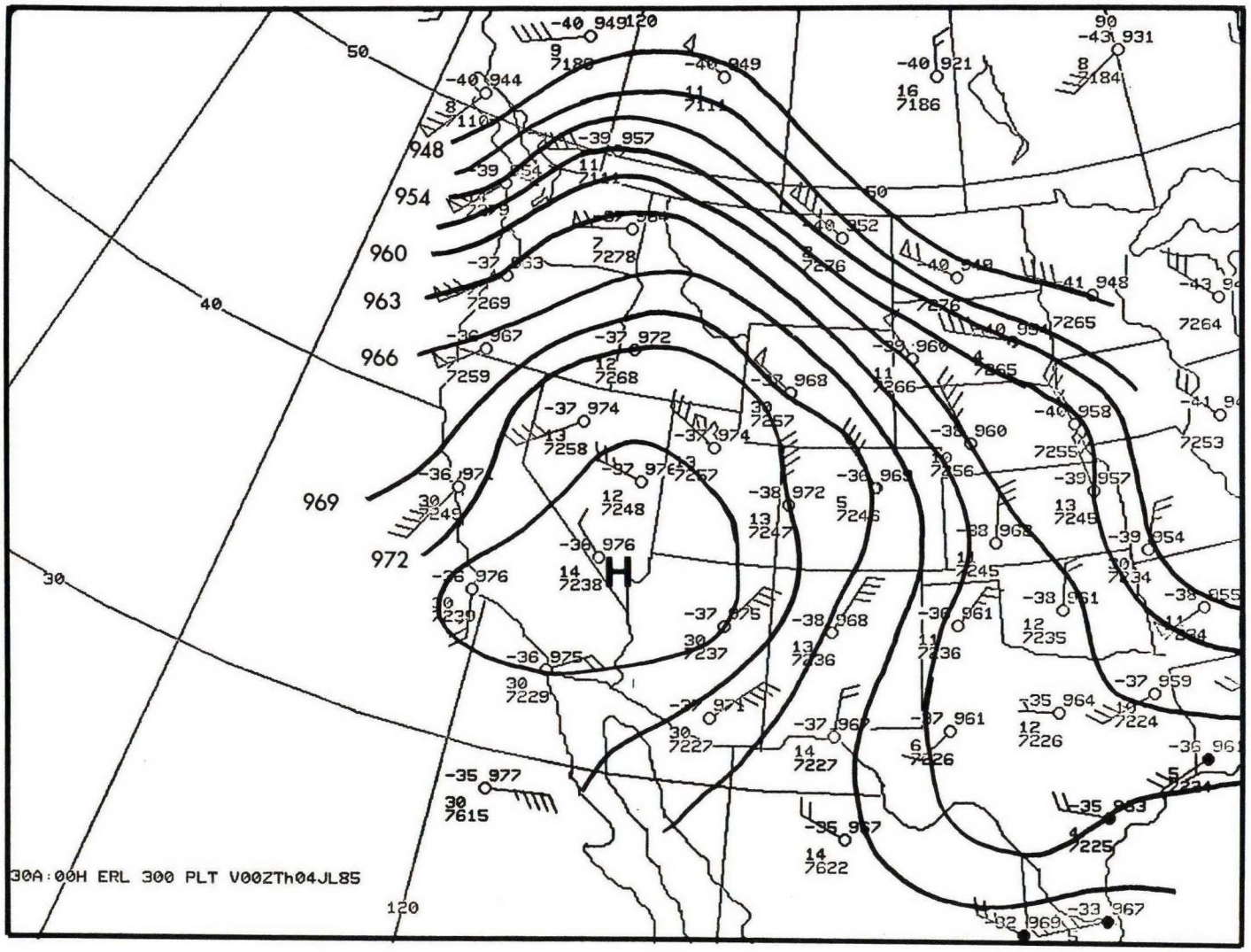


Figure 23. 300 millibar upper air chart, 1700 hours, July 3, 1985, showing the position of the subtropical high aloft at the time of the Wheeler fire's greatest run. Altitudes are in tens of meters.

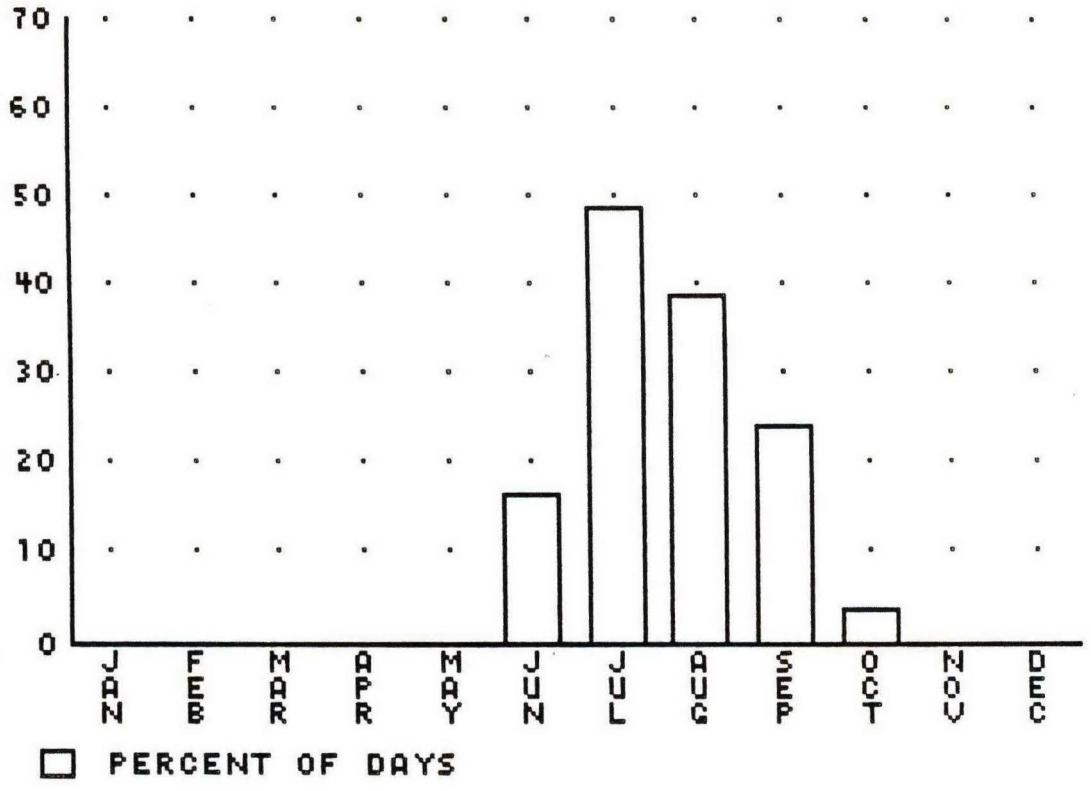


Figure 24. Frequency of the subtropical high aloft condition at Sandberg, California, 1951-1960, in percent of days per month experiencing the condition.

Source: Schroeder and others 1964

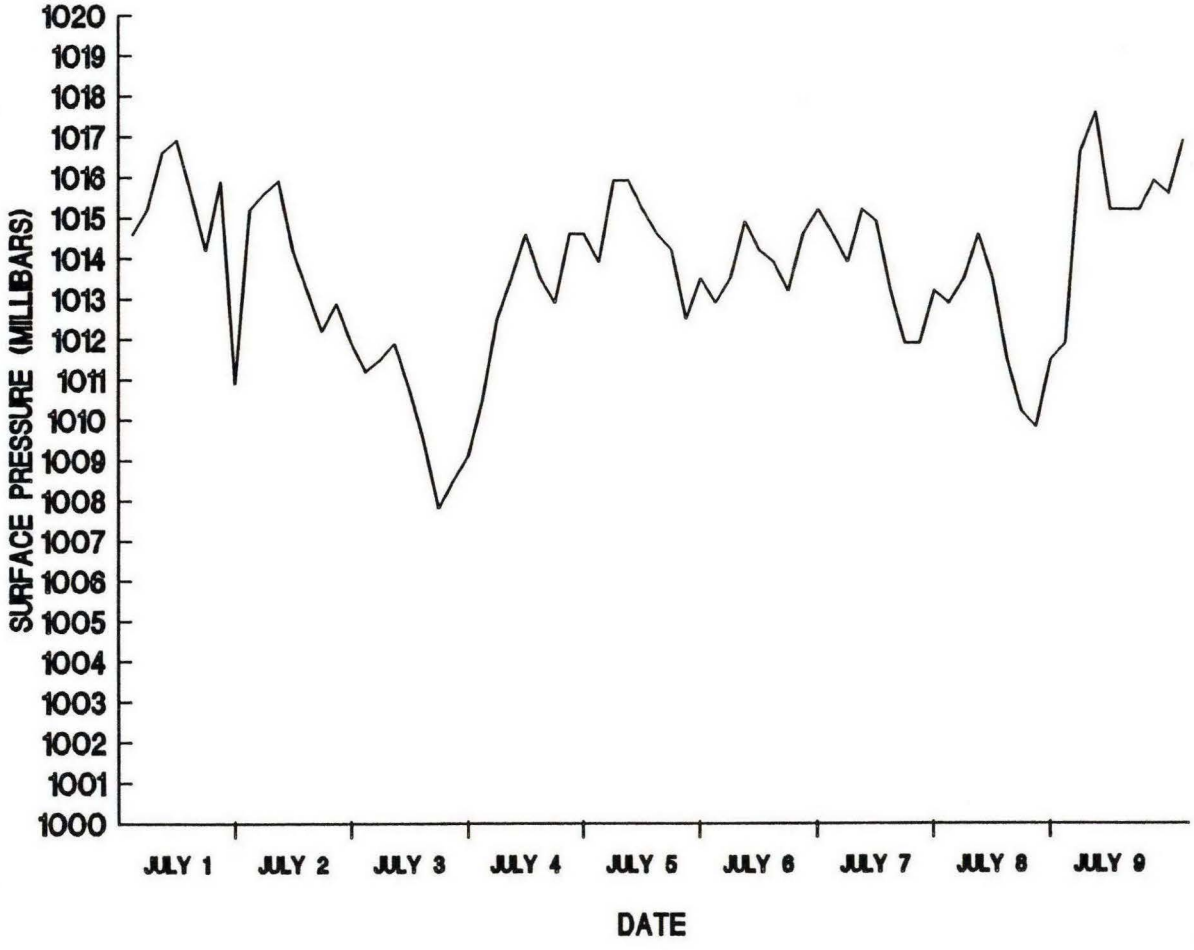


Figure 25. Surface air pressure at Santa Barbara, July 1 to July 9, 1985.

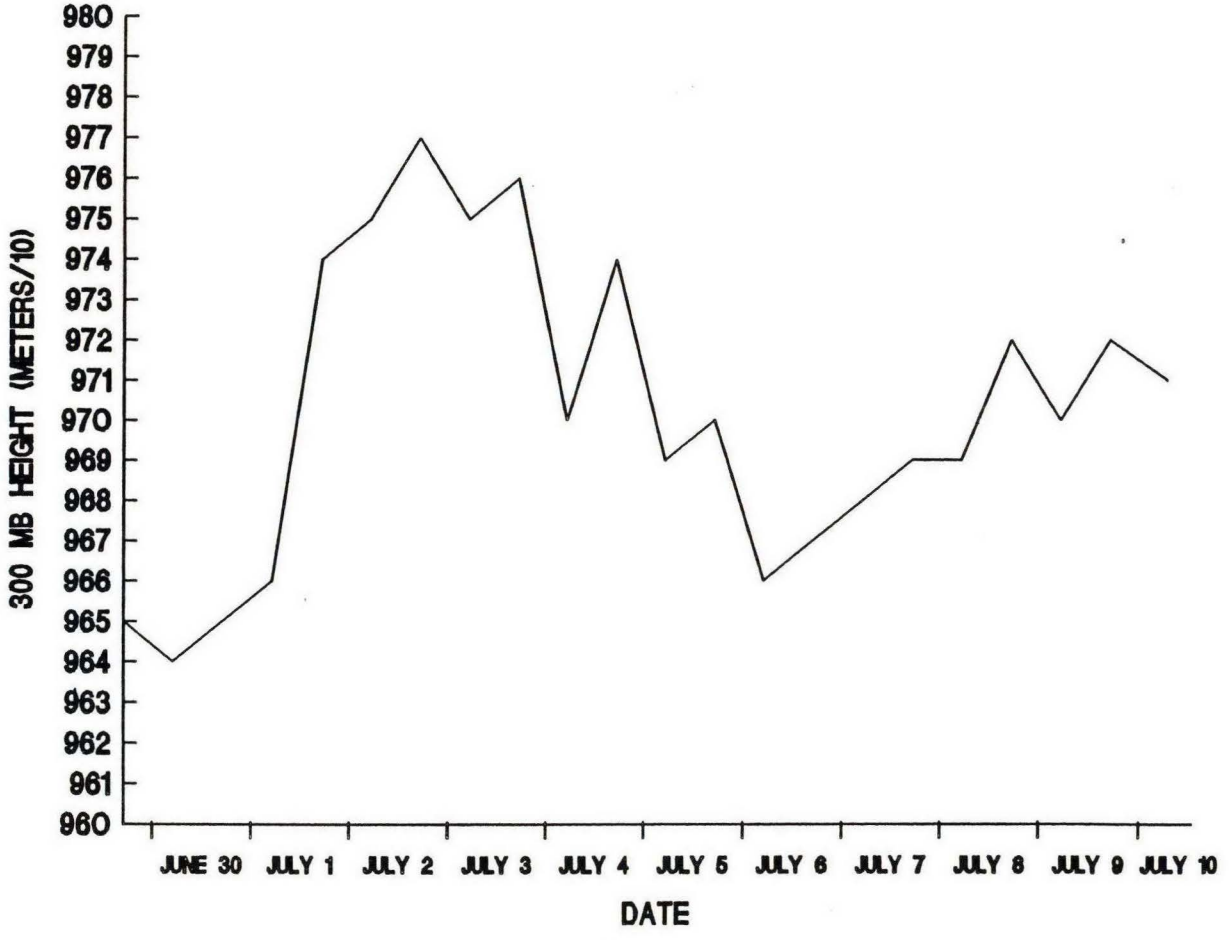


Figure 26. 300 millibar heights at Vandenburg Air Force Base, June 30 to July 10, 1985. Heights are in tens of meters.

Table 8. Hourly temperature and relative humidities for Santa Barbara and Ojai, July 3-4, 1985. Note the dramatic change in conditions after 2100 in Santa Barbara and 0200 at Ojai, as the marine layer infiltrated the area.

	SANTA BARBARA		OJAI	
TIME	TEMP	RH	TEMP	RH
1800 (July 3)	101° F	15%	97° F	22%
1900	99	18	95	24
2000	96	18	94	24
2100	96	18	93	24
2200	80	47	92	25
2300	66	69	88	24
0000 (July 4)	65	70	94	25
0100	63	73	93	26
0200	63	73	91	27
0300	64	73	77	37
0400	65	70	75	48
0500	62	81	73	53
0600	62	78	71	54

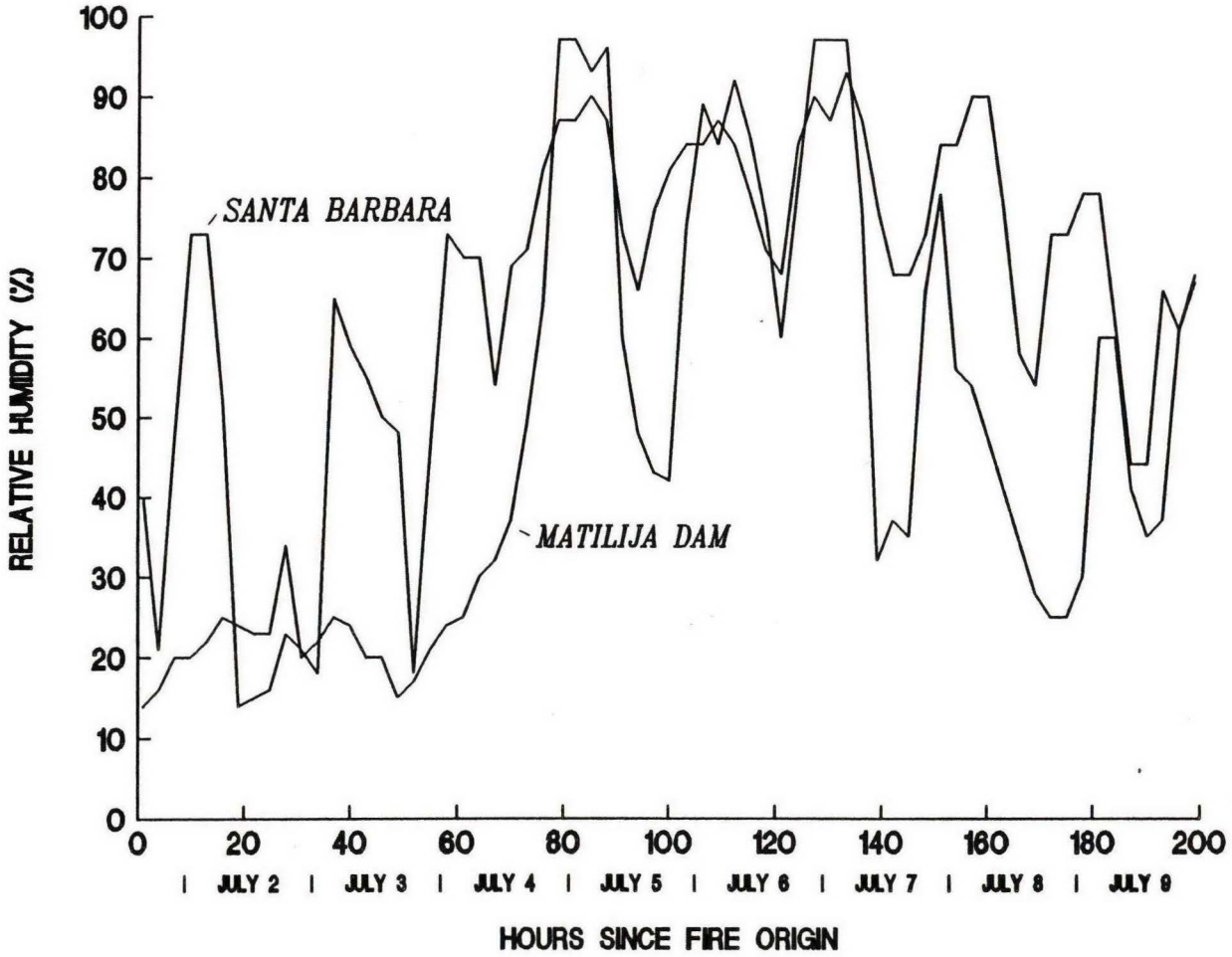


Figure 27. Relative humidities at Santa Barbara and Matilija Dam from July 1 to July 9, 1985.

Table 9. High temperatures and humidity ranges at Santa Barbara and Ojai from July 1 to July 12, 1985.

DATE	SANTA BARBARA			OJAI		
	High Temp.	Low RH	High RH	High Temp.	Low RH	High RH
July 1	95° F	21%	78%	101° F	23%	57%
July 2	109	14	73	98	28	56
July 3	101	18	65	107	20	30
July 4	76	54	87	94	25	97
July 5	71	66	90	87	49	97
July 6	69	68	90	78	71	97
July 7	69	68	93	90	45	97
July 8	80	54	90	98	31	97
July 9	82	44	78	92	41	90
July 10	82	47	78	85	46	95
July 11	79	41	81	90	45	96
July 12	73	55	81	88	45	97

Effects on fire behavior. Because of the variability and inconsistancy of winds on the Wheeler fire, the major efforts in weather analysis were focused on temperature and relative humidity relationships. It is well known that changes in temperature or relative humidity have significant effects on fire spread. However, temperature and relative humidity are not independent variables that can be separated and analyzed individually. In a given air mass, relative humidity is a direct function of temperature (Countryman 1971), and decreases as temperature rises. Since the Wheeler fire occurred, for the most part, under a single stagnant air mass, this relationship should have held true, and generally did (Figure 28). Dew point in this air mass was calculated to occur at about 59°.

It was felt that since temperature and relative humidity are inseparable but affect fire behavior each in their own way, combining the two elements into a single "factor" might reveal some correlation with observed fire behavior. This was accomplished by dividing the observed temperature (in degrees Fahrenheit) by the observed relative humidity (in percent). The resulting number gives a relative ratio between temperature and relative humidity. The actual scale is arbitrary and only indicates the relative relationships between differing conditions.

Most fire managers would agree that a temperature of 100° *and a relative humidity of 20 percent represents fairly extreme* fire weather. The resultant ratio of 100/20 equals 5.0. On the other hand, a temperature of 60° coupled with a relative humidity of 80 percent (mild fire weather) yields a ratio of only 60/80 or 0.75. Thus, the higher the ratio, the more extreme the combined weather conditions.

There are limitations to the usefulness of this formula that were not approached during the Wheeler fire. Since the formula relates only relative conditions, quite different conditions may give the same ratio. For example, a temperature of 60° and a relative humidity of 12 percent will also yield a ratio of 5.0, though fire weather would certainly not be as severe as in the situation above. Since the Wheeler fire occurred under a single air mass, such shifts in the relationships could not occur, and temperatures and relative humidities were always inversely related. However, caution should be used in applying this type of formula to fires occurring under shifting air masses.

By taking the average temperature and relative humidity (at Ojai) for each burning period of the Wheeler fire (burning periods were calculated from the period between IR photo flyovers and averaged 12 hours long) and comparing the resulting factor with the average rate of spread (in acres per hour) during the same burning period, it was possible to establish a relationship between weather and one aspect of fire behavior (Figure 29). As expected, the more extreme the weather conditions, the more rapid the rate of spread. What was not expected was the linearity of the relationship. Linear regression analysis revealed an R-squared value of 68.0 percent. In the case of the Wheeler fire, it

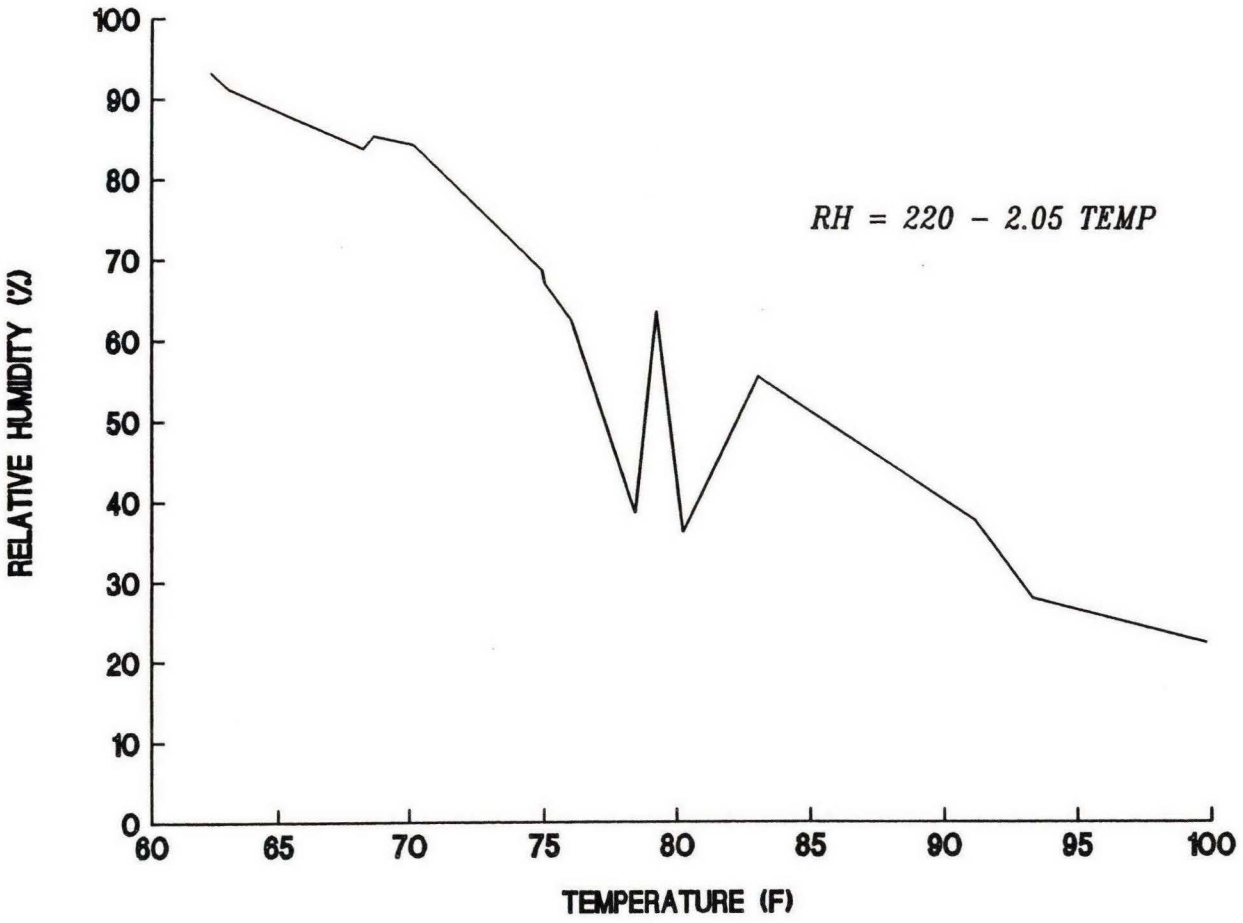


Figure 28. Relationship of relative humidity to temperature at the Ojai station during the Wheeler fire.

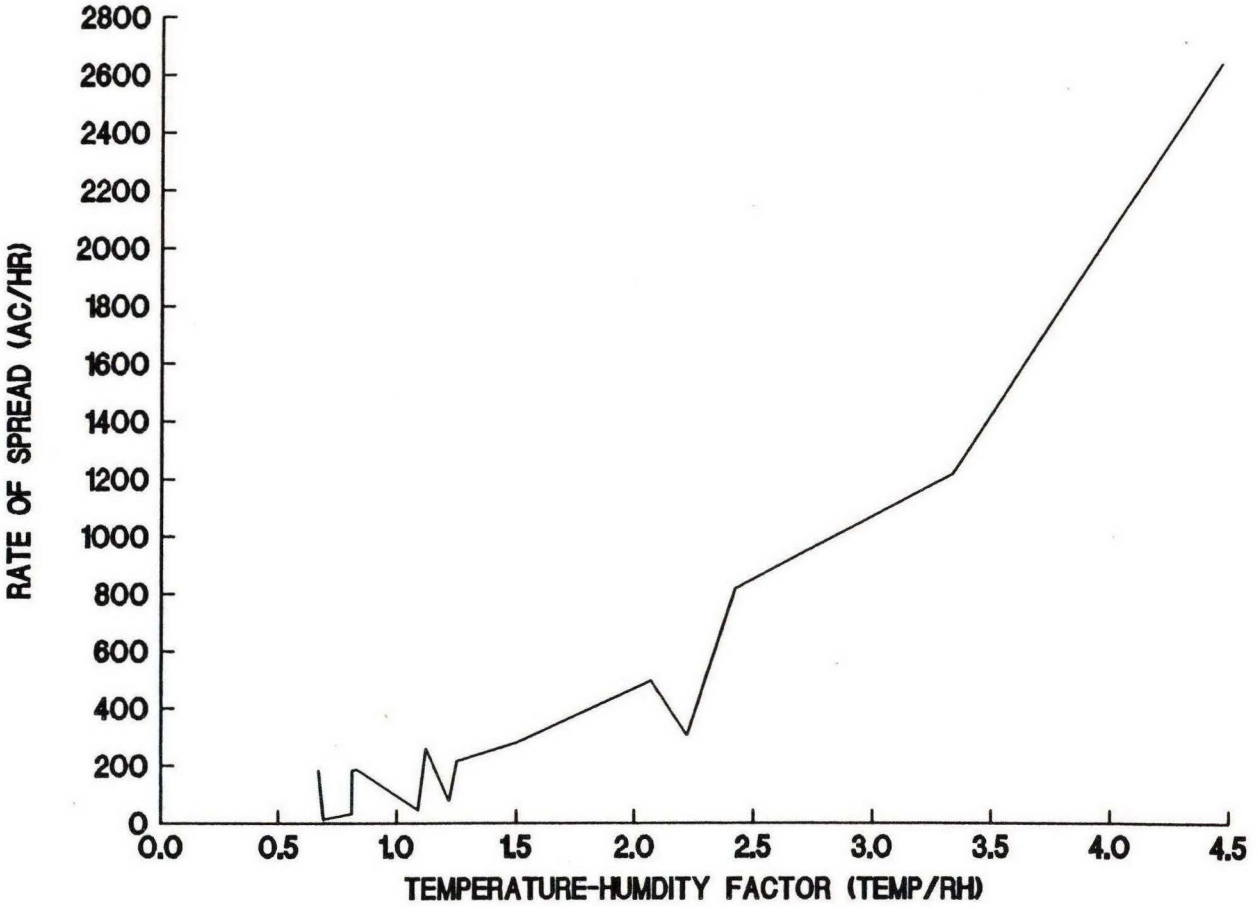


Figure 29. Relationship of rate of spread (in acres/hour) to the temperature/relative humidity factor for the Wheeler fire.

appears that it would have been possible to predict, with reasonable precision, the rate of area increase based solely on the temperature/relative humidity factor. However, much more research needs to be conducted before these findings can be given their proper weight. Still, the relationship is quite suggestive. When compared burn period by burn period (Figure 30), the close fit is even more evident and the major runs on July 3 and 8 are clearly indicated as are the diurnal fluctuations in rate of spread.

Looking more closely at the relationship between the temperature/relative humidity factor and rate of spread it is interesting to note the relative variability of rates of spread under moderate weather conditions. The Wheeler fire experienced only three truly extreme burning periods, where the average rate of spread exceeded 800 acres per hour. The other twelve burning periods studied were not nearly as severe, most having average rates of spread less than 300 acres per hour. In order to determine the relationships between rate of spread and the temperature/relative humidity factor during the less severe buring periods, a linear regression analysis was conducted excerpting the three worst burning periods. Without the most severe burn periods, the R-squared value dropped from 68.0 percent to 52.0 percent. An even more severe drop was seen in the relationship between rate of spread and temperature alone, from an R-squared value of 66.7 percent to 30.0 percent.

The apparent implication here is that under more moderate temperature/relative humidity conditions, other factors (such as wind, fuels or terrain) replace temperature and relative humidity as the main controlling factors determining fire spread. This supports the concept of fire behavior as a complex of interacting factors of varying influence. As temperature and relative humidity become more extreme, they begin to account for a larger porportion of the expressed fire behavior, masking the effects of terrain and fuels, which become less and less important. This has two implications for fire behavior prediction: 1) that under moderate conditions, temperature and relative humidity may be poor predictors of fire spread and should perhaps be given less weight in fire behavior calculations; and 2) the opposite, that under severe conditions, temperature and relative humidity may be vital factors in determining fire spread and may be used with good accuracy in fire behavior calculations.

Sundowner winds

On the Wheeler fire, moderate to severe sundowner winds occurred along the front ranges on the evenings of July first, second and third, driving flames into the outskirts of Ojai and Meiners Oaks, forcing mass evacuations and consuming ten homes. Typically for sundowners, the winds began at about 1800 and continued sporadically until after midnight.

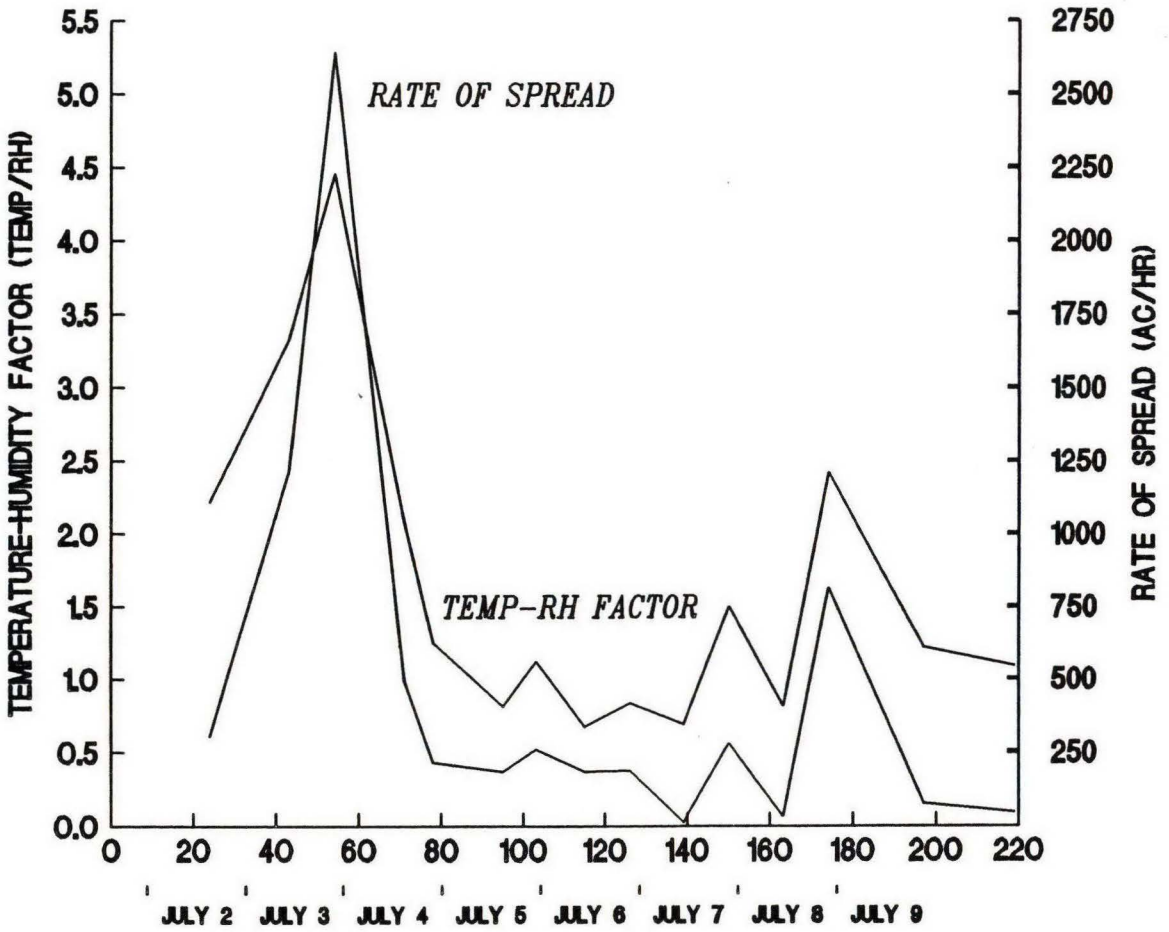


Figure 30. Comparison of temperature/relative humidity factor to rate of spread for 15 burning periods during the Wheeler fire, from July 1 to July 8, 1985.

Early on the morning of July 2, while the Wheeler fire was still confined to the interior area, a second fire began in Cozy Dell canyon, on the coast side of the mountains. This second blaze began burning upslope toward Nordhoff Ridge until about 0230, when sundowner winds began pushing it back toward Ojai. Within two hours, the fire was threatening Camp Ramah and evacuation of the town's outskirts had begun. Again, on the evening of the 2nd, the sudden appearance of sundowner winds pushed the fire across Highway 33 at Matilija Dam, opening the way of the fire's major advance to the west. Evacuations and structure protection continued in Ojai and Meiner's Oaks.

The night of July 3 was the last appearance of sundowner winds during the Wheeler fire. At about 1800, sundowner winds surfaced all along the front ranges, raising the temperature in Santa Barbara by 25^{o} while the relative humidity dropped by 30 percent (Figure 27). Windspeeds for this sundowner were not as extreme as have been occasionally recorded, varying between 10 and 25 mph. Figures 31 and 32 show the influence of the sundowner winds along the coast on the night of the third. The winds were strongest and most persistent near Ojai, where the winds surfaced on and off until about 0300 on July 4.

Effects on fire behavior. As with the 1948 Wheeler Springs fire and the 1971 Romero fire, sundowner winds on the Wheeler fire gave rise to erratic fire behavior and created severe control problems. The coastward location of settlements only exacerbated the situation. Generally speaking, the sundowner winds on the Wheeler fire, though perhaps not strong as on earlier fires, had very similar effects on fire behavior. With the replacement of the usual onshore flow of moist air with hot, dry downslope winds, moderately burning flanks became rapidly advancing fronts. Control lines and fuel breaks were lost, and the fire only stopped when it reached the edge of the settled areas. It is interesting to note that though the sundowner winds are generally downslope, there was a net movement to the east on the Romero, Wheeler Springs and Wheeler fires. This may be partially explained be realizing that the normal diurnal onshore winds in the area are usually from the south or southwest. Thus, during the day, the fire is pushed upslope and to the east, while the sundowner winds at night force the fire back downslope, creating a zigzagging fire front.

Marine influence

A well defined layer of cool, moist "marine air" is a nearly ubiquitous characteristic of coastal California during the summer months. This layer forms as air passes over upwelling cool water just off the coast. The cool water, in conjunction with the cool nighttime land surface, absorbs heat from the air, lowering its temperature to near the dew point. Fog or low clouds are common, especially during the night and morning hours before solar

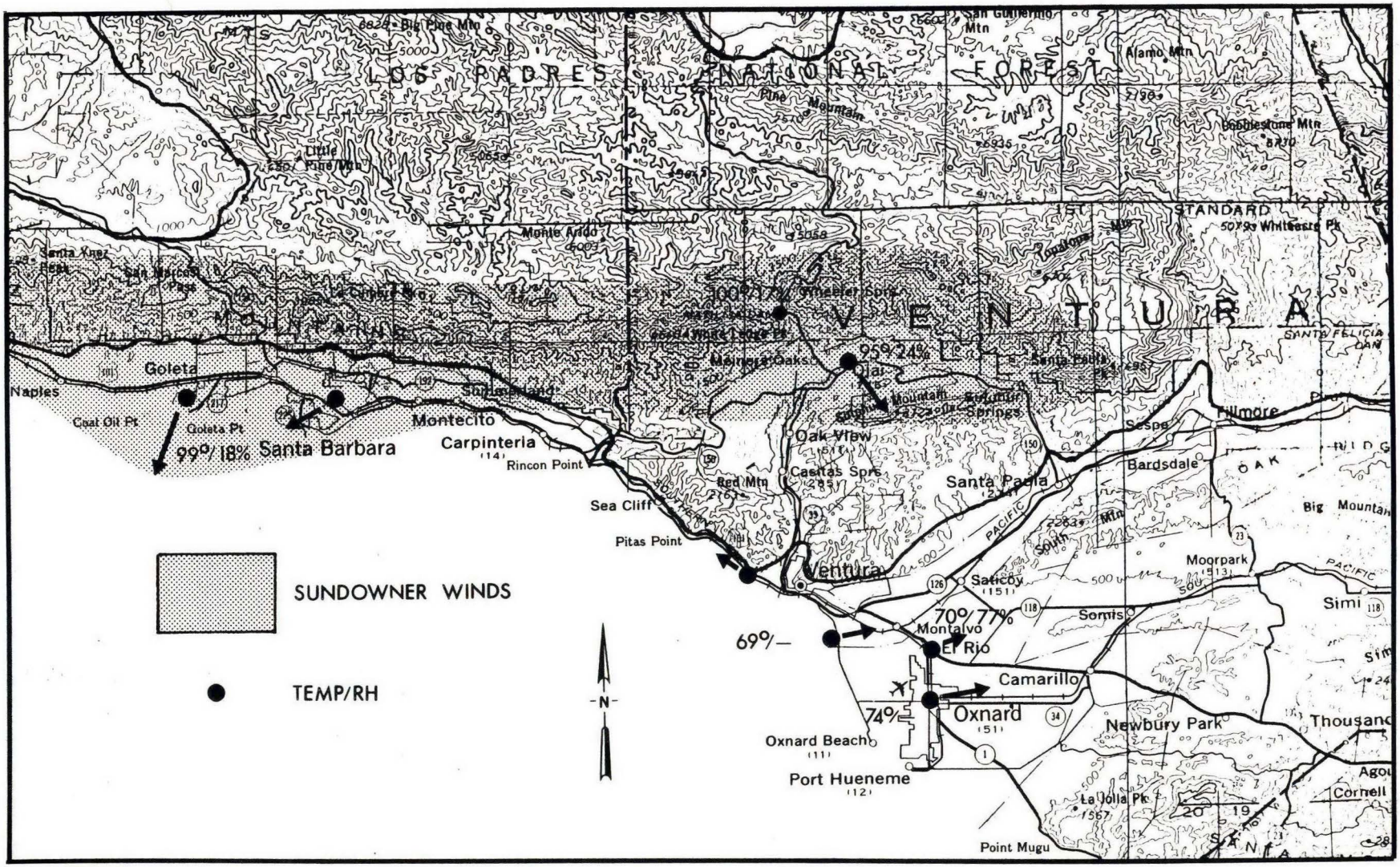


Figure 31. Extent of sundowner winds in the Wheeler fire area, 1900 hours, July 3, 1985. The winds at this point extended from Goleta to east of Ojai. Winds speeds averaged 15-20 mph. Note the strong marine influence in the area of Oxnard.

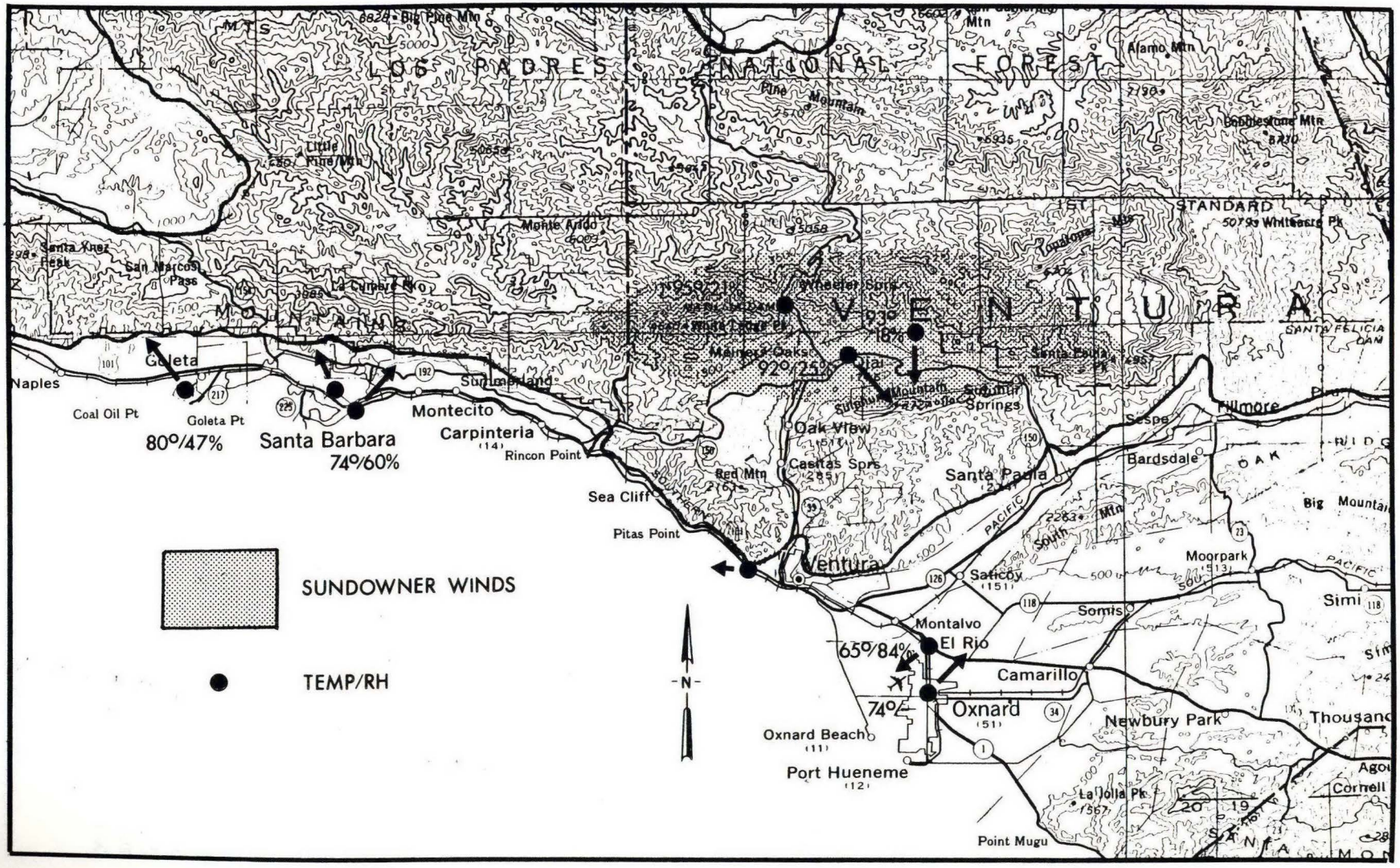


Figure 32. Extent of sundowner winds in the Wheeler fire area, 2200 hours, July 3, 1985. The winds have retreated from the Santa Barbara area, and moist marine air is beginning to re-invade the coast.

insolation reheats the land. The depth of the marine layer varies, though 1000-2000 feet is common. At the top of the layer is a highly stable inversion which prevents mixing of the marine layer with the warmer, drier air above (Coffin 1959, Schroeder 1960). In places where the terrain permits, the marine layer has been known to penetrate as far as 70 miles inland.

Effects on fire behavior. The presence or absence of well defined marine layer was a vital factor affecting fire behavior on the Wheeler fire. During the first three days of the fire, when the subtropical high aloft was particularly strong, the marine layer was very shallow and limited to the immediate coast. Under this condition, sundowner winds were able to reverse the onshore flow readily, even at coastal locations such as Santa Barbara. However, late on the night of July 3, the upper level high began to weaken and marine air re-invaded the coastal portions of the fire area (Figure 27). The southwestern front of the fire, which had spread west four miles from 1000 to 2100 on July 3, died down with the influx of the marine layer and by the evening of the 4th was virtually cold. For the next three days the marine layer remained strong (Figure 27) and there was virtually no activity on the south side of the fire (Figure 33). It was not until the marine layer weakened on July 8 and the relative humidity dropped (Figure 27) that the backfiring operation begun on Laguna Ridge on the 4th was completed (Figure 33).

After the night of July 3, the marine layer was deep enough and strong enough to seriously hamper all burning operations on the coast side of the mountains. Burning operations begun along Sisar Road on the evening of the 4th were completely without success as were burning operations begun near Noon Peak on July 5. However, the fire continued to spread readily in the inland areas out of the reach of the marine influence. While burnouts were sputtering along Sisar Road, a burnout along Highway 33 got out of control and jumped the road, spreading over a mile to the northeast before it was finally controlled. For the entire length of the fire, burnout operations in the inland area of the fire were conducted with greater success than on the coast side.

It is clear that the presence of the marine layer dramatically affects fire behavior. But in exactly what way? Is it merely the change in relative humidity? Does the sudden drop in temperature affect the volatilization of flammable compounds? Though the answer may seem simple, the speed with which fire behavior can change casts doubt on simple answers. The response of the Wheeler fire to the influx of the marine layer was virtually instantaneous. Fuels that had been burning actively for days suddenly would not sustain a flame. But it takes hours for dead fuels and days for live fuels to respond changes in relative humidity, much too slow for the changes observed on the Wheeler fire. Further research is needed before the mechanism behind these changes in fire behavior can be understood.

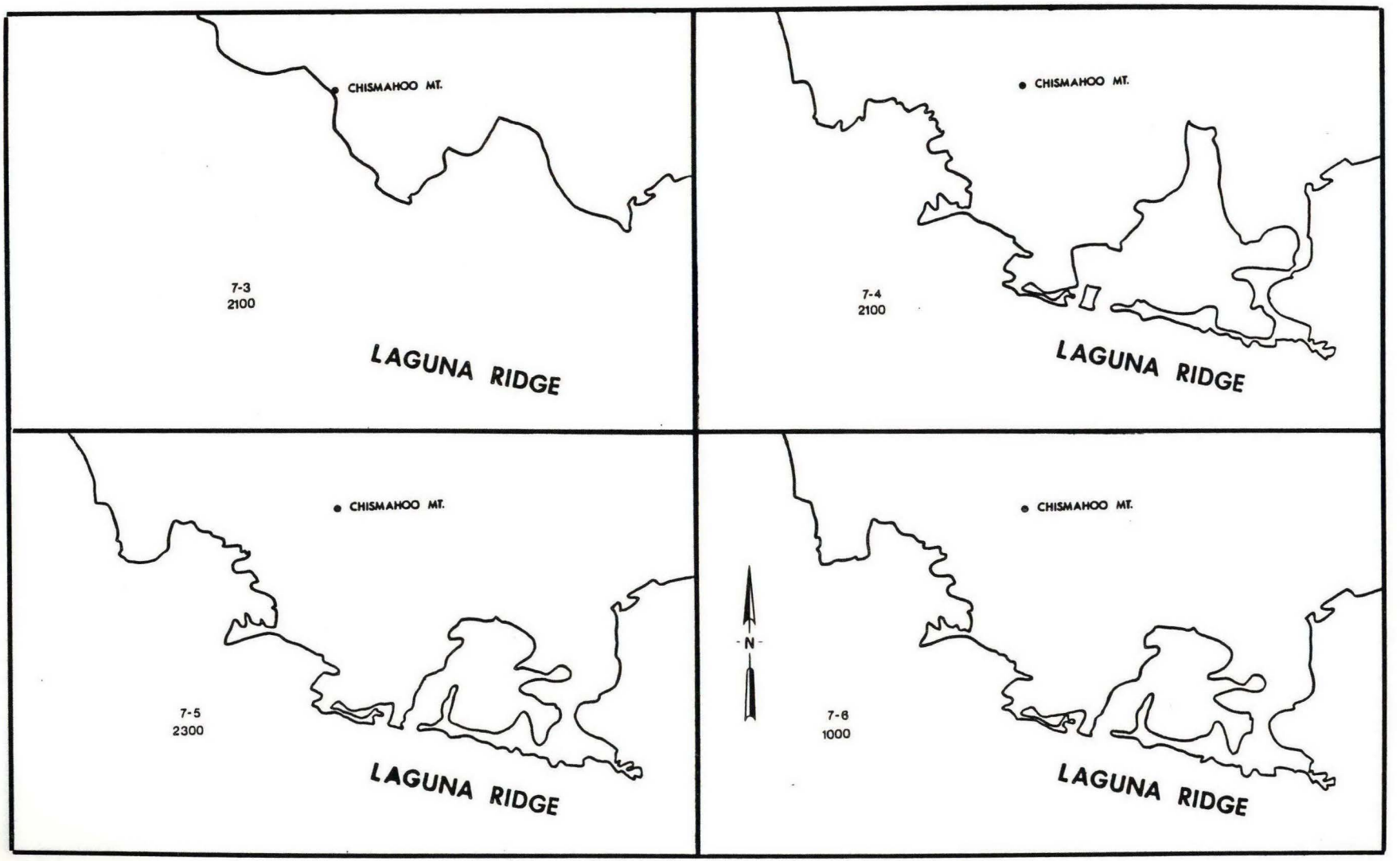


Figure 33. Advance of the southwestern front of the Wheeler fire from 2100 hours on July 3, 1985 to 1800 hours on July 10, 1985.

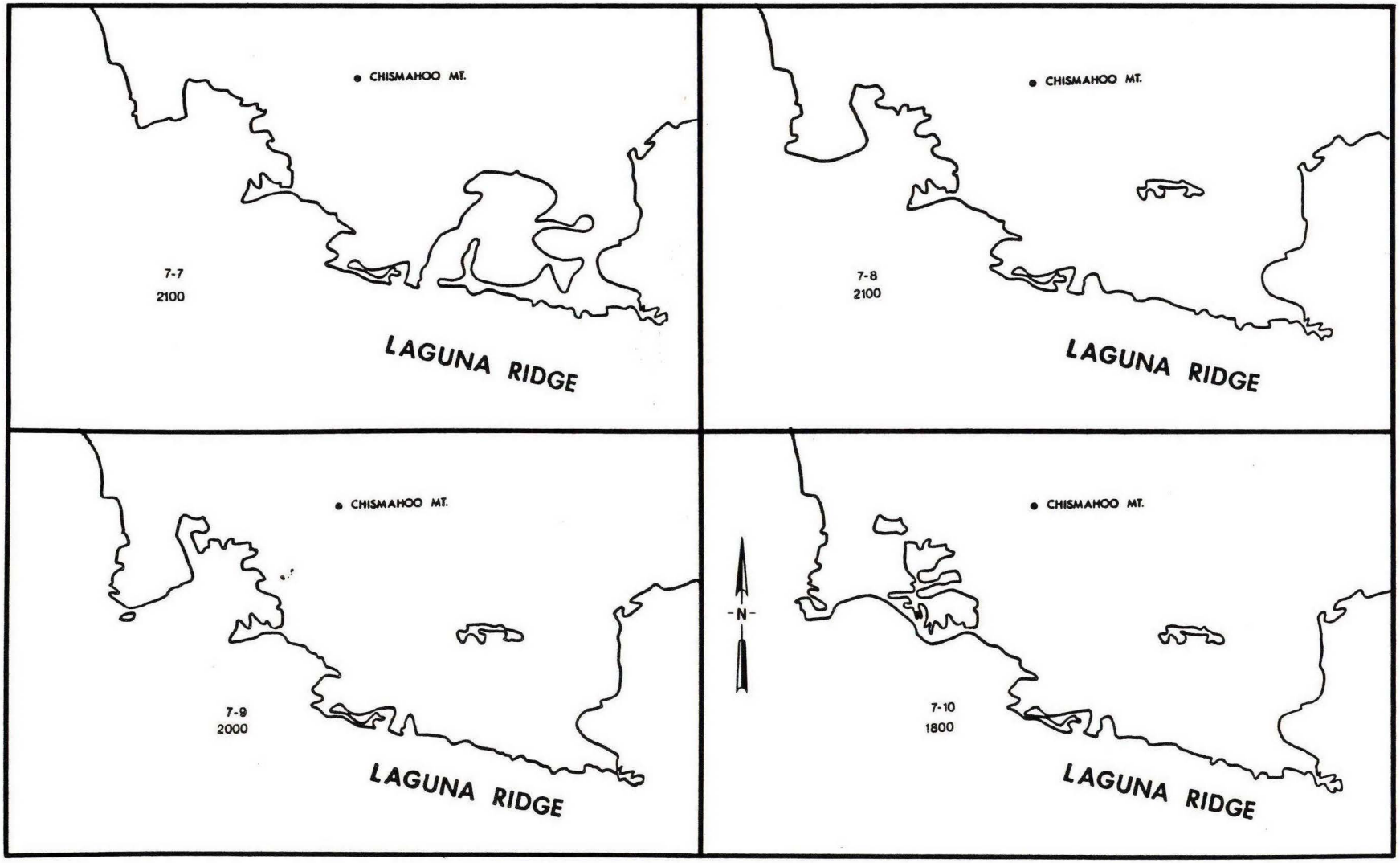


Figure 33 (continued).

Fire influenced weather and blowup conditions

Late on the morning of July 3, as previously noted, the Wheeler began its major run up Matilija Canyon. By evening, the fire had traveled seven miles and consumed over 30,000 acres. Unauthorized backfires lit by residents in Matilija Canyon were said to have contributed to the extreme fire behavior as the fire front ran to meet the backfires. Many people remarked that parts of Matilija Canyon resembled nothing so much as a barren moonscape after the fire's passage, with six inch thick oak trees burned even with the ground.

A classic blowup situation, similar in some ways to the major run of the Matilija fire of 1932. But what exactly gave rise to such extreme behavior? Unfortunately, there is too little data available to do more than speculate on the causes of the Wheeler fire blowup. Certainly the high temperatures and low humidities that had persisted for the preceeding four days were a major factor, as already discussed. It is also possible that the location of the blowup was a major contributing factor. The blowup occurred in Matilija Canyon, a very deep and narrow east-west trending gorge. With the entrance of the fire into this canyon along its north side, a number of things may have occurred. First, heat from the fire radiating across the canyon may have preheated fuels to an explosive level. Second, the nature of the canyon is such that convectional air movement caused by the heat of the fire may have turned the canyon into a wind tunnel. Though there are no recorded accounts of severe winds in the canyon, it is possible that strong upcanyon winds may have developed as air was drawn through the canyon's narrow opening toward the fire. Once triggered, these winds may have pushed the fire up the canyon at an unprecedented rate, lofting fire brands as much as a mile ahead of the fire front. These are mere speculations, but it is interesting to note that the blowup of the 1932 Matilija fire began at about the same time of day soon after it had entered Sespe Gorge, another deep east-west trending canyon in the area. It may be that certain combinations of topography and weather conditions in the area are highly conducive to blowups, but without more detailed information, we can do little more than guess the catalyzing mechanism of the Wheeler fire blowup.

Fuels as a Factor in Fire Spread and Perimeter Formation

Fuels are an all important factor in fire behavior. Indeed, all fire behavior models in use today are heavily dependent on fuel parameters for determining rate of spread calculations. Rightly so. But in the case of chaparral fuels, it is becoming apparent that we currently lack sufficient knowledge of its characteristics to make accurate predictions and that the existing fuel models are inadequate. Unlike grassland fuels and the forest understory fuels of the west which display a nearly

uniform fuel bed, chaparral fuels are highly variable, both in species composition and fuel bed arrangement. Chaparral fuels are also highly three dimensional, with the bulk of the biomass suspended two to six feet above the ground. This unique arrangement is not taken into account by fire behavior processors which were developed for the uniform and compact fuel beds of forest understories and grasslands. Furthermore, a typical mixed chaparral community may consist of as many as five or six different major species, each with its own peculiar burning characteristics. Differences in the relative importance of each species from stand to stand can have noticable effects on the burning characteristics of the stand as a whole. And it is becoming apparent that seemingly minor changes in environmental conditions can have a dramatic effect on the burnability of chaparral fuels. Combined, the chaparral emerges as an extremely complex fuel type, subject to influences yet to be measured or accounted for in fuel models. Because of this, the present analysis will be limited to examining the reaction of the Wheeler fire to gross changes in fuel age and fuel type rather than a detailed analysis of fuel characteristics.

Fuel Types

An accurate analysis of the response of wildfire to the various fuel types present would be a helpful tool for fire behavior prediction. However, detailed vegetation type data for the Wheeler fire area is nonexistent and would entail years of field work to collect. The best available type data for the area are the VTM (Vegetation Type Map) blue-line maps. These maps are fraught with shortcomings, primarily their age (the data for these maps was collected in the 1930's) and the gross level of fuel type differentiation. Still, if these shortcomings are kept firmly in mind, the maps can still reasonably be expected to yield some valuable information. Comparison of the VTM maps to recent aerial photos reveals a high accuracy in vegetation type boundaries, indicating that these have not changed severely in the intervening 50 years.

The VTM maps recognize 20 major fuel types in the state, twelve of which were present to one degree or another within the perimeter of the Wheeler fire (Table 10). Chaparral associations accounted for over 85 percent of the area consumed in the fire (Figure 34). The nine other associations together accounted for less than 16,000 acres of the total area burned.

Presumably, each of these fuel types have different levels of flammability and may display a greater or lesser tendancy to burn under given conditions. In order to test this, the fuel type composition of the burned areas was compared to that of the islands within the perimeter of the fire. Though this precludes testing for the effects of fuel type changes on perimeter formation, there is no reasonable way to include fuels outside of

Table 10. VTM fuel types present within the perimeter of the Wheeler fire. Percentages indicate consumed areas and islands within the primary perimeter of the fire.

FUEL TYPE	VTM TYPE#	ACRES BURNED	% OF BURNED AREA	% OF ISLANDS
Chamise Chaparral	5	63,980	59.34	34.12
Mixed Chaparral	6	27,147	25.18	43.56
Oak Woodland	9	8,137	7.55	12.11
Sagebrush	4	3,477	3.22	0.30
Bigcone Spruce	11a	1,912	1.77	6.61
Cultivated & Urban	3	1,245	1.16	0.77
Semidesert Chaparral	7	1,209	1.12	1.89
Sagebrush/Woodland	4W	292	0.27	0.13
Grassland	2	199	0.18	0.00
Barren	1	119	0.11	0.51
Woodland/Grass	8	96	0.09	0.00
Pinon/Juniper	10	15	0.01	0.00

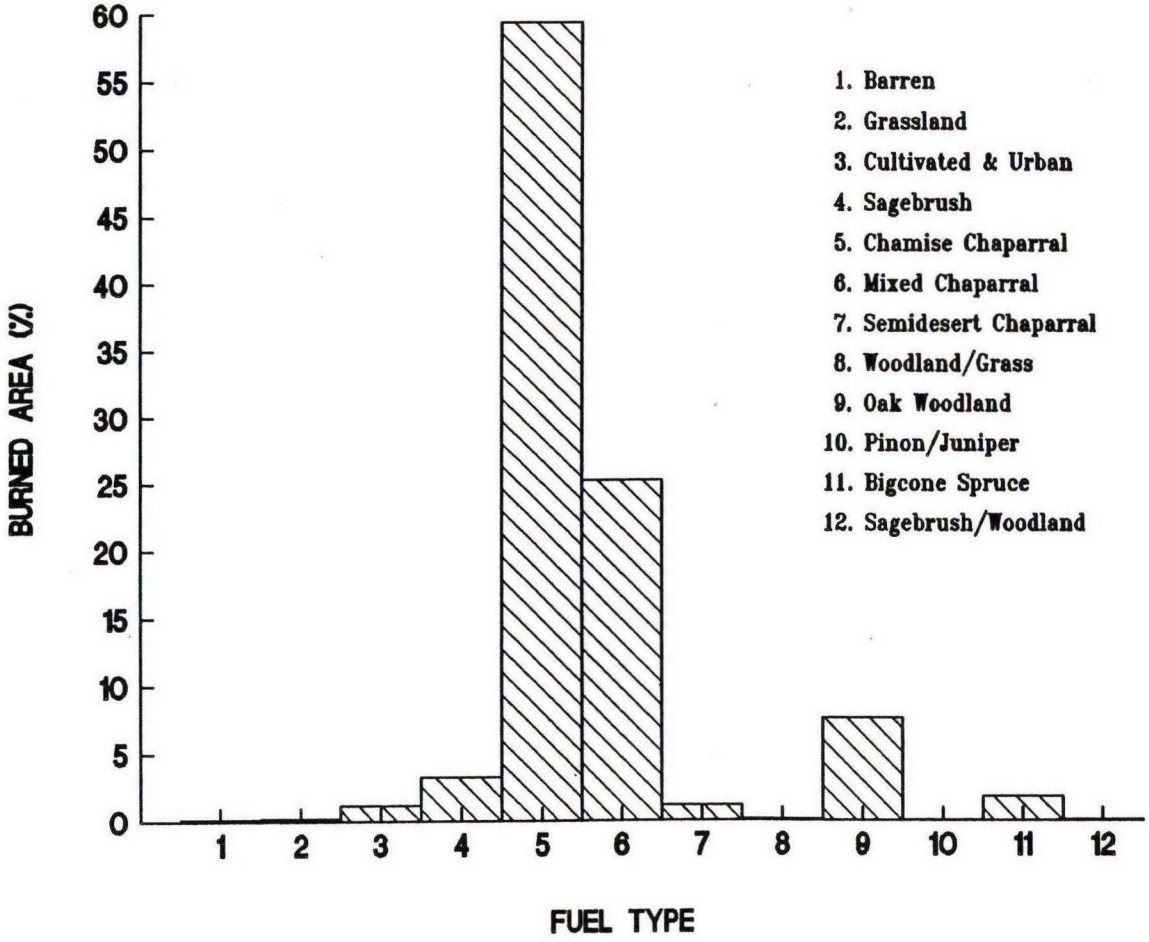


Figure 34. Porportion of the VTM fuel types within the area consumed by the Wheeler fire.

the primary fire perimeter without introducing an arbitrary bias into the analysis. Since the area burned (107,828 acres) is many times that of the islands (9,076 acres), a direct comparision of fuel type acreages in burned and unburned areas would be worse than misleading. Therefore, the porportional composition of fuel types in the burned and unburned areas were compared (Table 10).

Though a sample of one fire is small and some fuel types accounted for only a handful of acres within the fire, it was felt that an analysis might at least show some general trends. By dividing the percentage of unburned by the percentage of burned area for each fuel type, we obtain a ratio that gives a rough idea of the relative flammability of the fuels in the area of the Wheeler fire. The actual formula used was

$$\{[\%\ \text{unburned} / \%\ \text{burned}] - 1.0\} \times 100$$

and indicates the porportional change from unburned to burned (Table 11; Figure 35). A number greater than 0.0 indicates that the fuel was more prevalent in the unburned areas and may, therefore, be less flammable. This is supported by the fact that "Barren" and "Bigcone Spruce" (two fuel types that would be considered relatively non-flammable) have the highest positive porportional changes. A number less than 0.0 indicates that the fuel type is relatively highly flammable, and -100.0 denotes a fuel type that was completely consumed within the perimeter of the fire. Again, this is supported by the fact that "Grassland", "Woodland/Grass" and "Sagebrush" all show large negative porportional changes (Table 11; Figure 35). It is interesting to note that "Mixed Chaparral" displayed a slight relative resistance to burning while "Chamise Chaparral" showed a slight relative tendancy to burn. This is probably due to the fact that "Mixed Chaparral" is more common on the more mesic north-facing slopes, while "Chamise Chaparral" usually occurs on drier south-facing slopes. It must be stressed that this analysis is relative in nature, indicating only which fuel types appear to be more or less flammable than others. Also, as some of the fuel types (e.g., Pinyon-Juniper) occurred on only a few acres in the fire area, there is plenty of room for other factors to mask their actual relative flammability.

Fuel Age

For the most part, the fuels consumeded during the Wheeler fire were between 35 and 55 years old (Figure 36). This is not due, as we shall see, to any inherent inflammability of younger fuels, but more to the general absence of young fuels in the Wheeler fire area. The vast majority of the Wheeler fire area burned in the 1932 Matilija fire, creating a baseline of 53 year old fuels in the area. About 25,000 acres within the Wheeler fire also burned in the 1948 Wheeler Springs fire, representing the

Table 11. Porportional change from island to burned area for each fuel type present within the perimeter of the Wheeler fire. A positive number indicates a resistance to burning, while a negative number suggests a high relative flammability. A value of -100.0 indicates that no islands occurred.

FUEL TYPE	VTM TYPE#	PORPORTIONAL CHANGE (%)
Barren	1	363.6
Bigcone Spruce	11a	273.4
Mixed Chaparral	6	73.0
Semidesert Chaparral	7	68.8
Oak Woodland	9	60.4
Cultivated & Urban	3	-33.6
Chamise Chaparral	5	-42.5
Woodland/Sagebrush	4W	-51.9
Sagebrush	4	-90.7
Pinyon/Juniper	10	-100.0
Woodland/Grass	8	-100.0
Grassland	2	-100.0

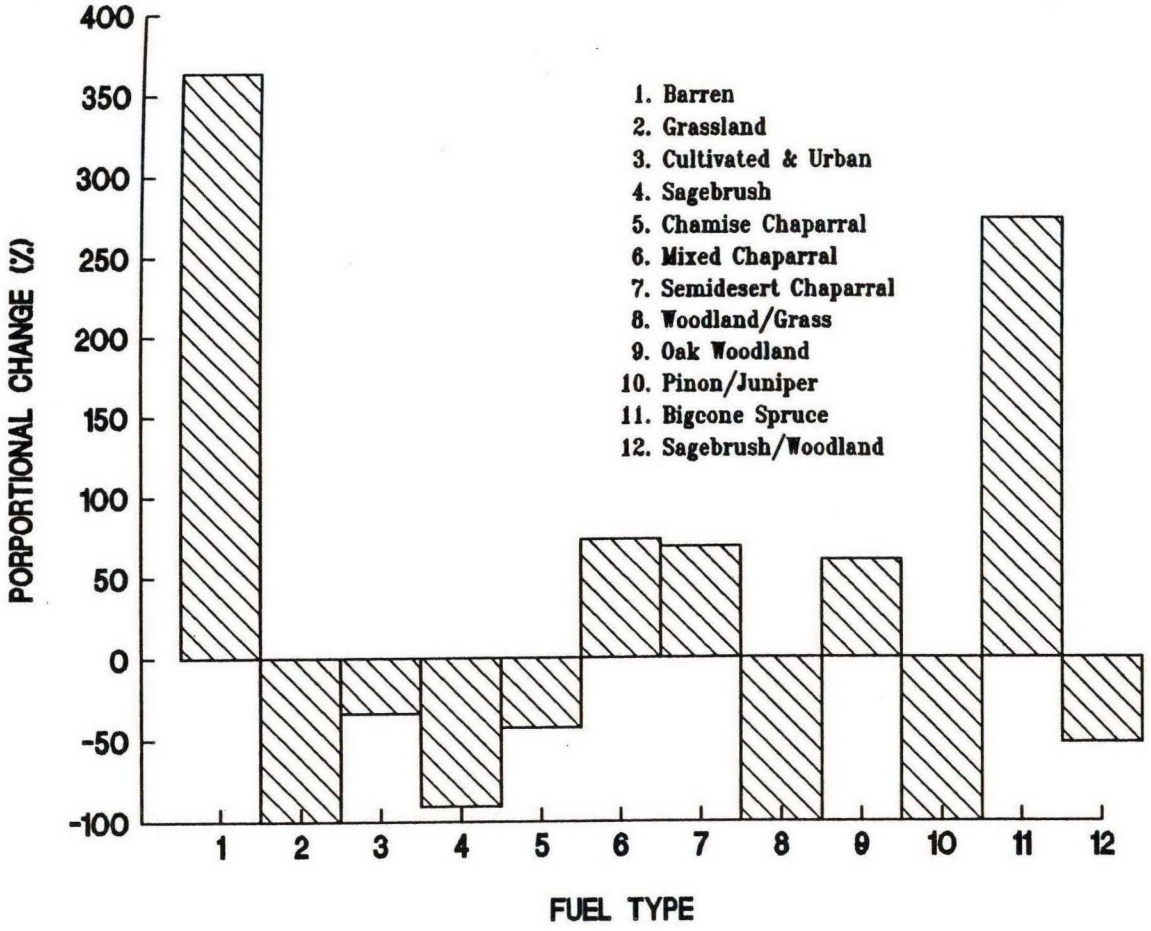


Figure 35. Porportional change for fuel types from percentage of burned areas to islands within the perimeter of the Wheeler fire. Positive numbers indicate a relative resistance to burning.

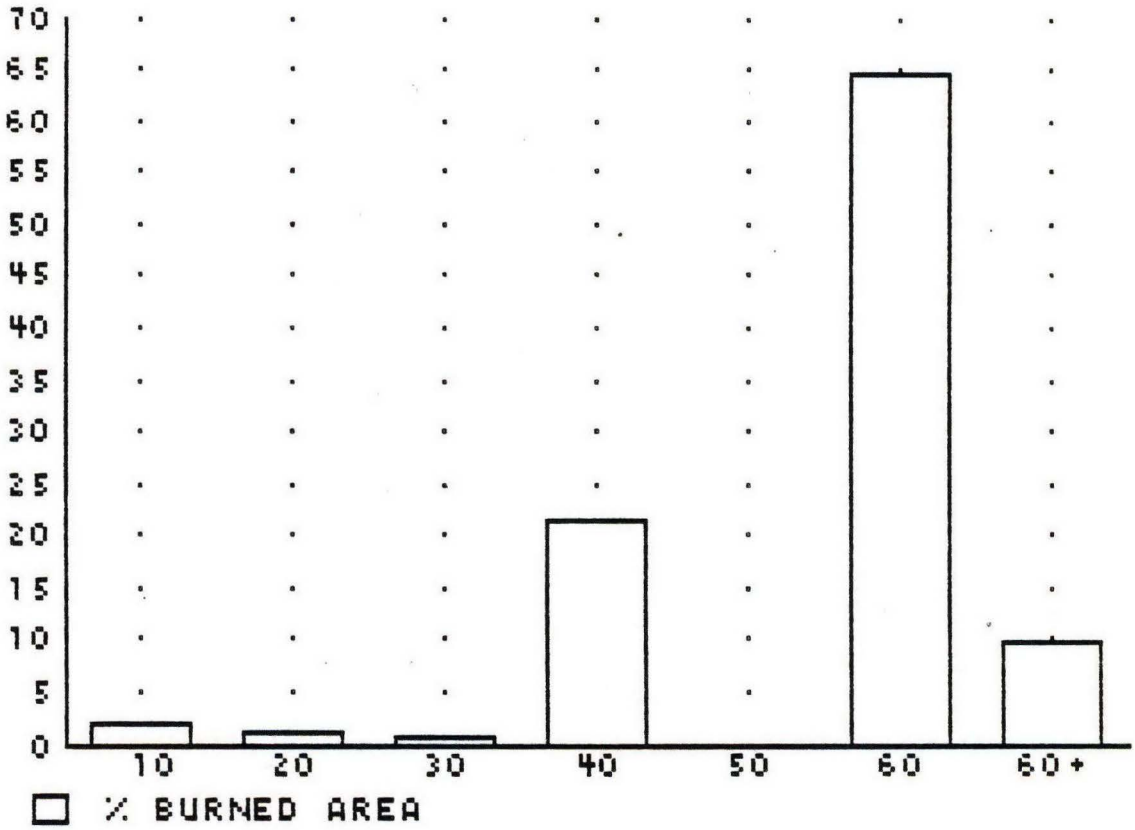


Figure 36. Percentage of fuels consumed in the Wheeler fire, by age class.

other major fuel age class within the Wheeler fire perimeter. All other fires in the area since then have either been fairly small or have occurred primarily outside of the Wheeler perimeter.

A considerable body of literature has been written about the virtues of "fuel age mosaics" as a means of controlling the spread of large fires (Dodge 1972, Minnich 1983, Philpot 1974, among others). Much of the thinking along these lines has emerged from chaparral fuel models derived from the analysis of 16 chamise shrubs collected in 1964 and 1965 at one site in Southern California (Countryman and Philpot 1970). These models are based on the assumption of an ever increasing percentage of dead fuels as the stand ages (Rothermal and Philpot 1973). This assumption is necessary in order to incorporate the fuel models into the Rothermal fire spread model (Rothermal 1972), which is driven primarily by the dead fuel component.

We immediately run into three problems. First, the fuel data from which the fuel models were created came from an exceedingly small sample of a single species (chamise) from a single location. Anderson and others (in press) have pointed out the high variability of chaparral fuels, suggesting the need for larger samples. Second, the assumption that the percentage of dead fuels increases continually throughout the life of the plant is difficult to support (Anderson and others in press). In the 22 years since it was sampled by Countryman and Philpot (1970), the percent dead material in the stand at North Mountain has only increased three percent, from 24.4 percent to 27.5 percent, though the shrubs are now 55 years old (data on file, U.S. Forest Service, Riverside). Third, the Rothermal fire spread model was developed for use in forest understory and grassland fuels, where the dead fuel component may account for up to 100% of the fuel bed. As previously stated, the characteristics of chaparral fuels are essentially incompatible with the existing fuel models, consisting, as they do, primarily of live fuels suspended a number of feet above the surface.

Still, there is no one who has not heard numerous stories of raging wildfires that fizzled and died upon coming in contact with a fuel age boundary. In fact, just such stories have been told concerning the Wheeler fire's interaction with the 1972 Bear and 1971 Romero fires.

The Wheeler fire provides us with a prime opportunity for examining the relationships between fuel age and flammability since it interacted with a number of recently burned areas. The following sections discuss and evaluate the fire's interaction with these burned areas and the relative value of fuel age management for fire suppression.

The 1971 Romero fire. The history of the Romero fire has been covered in a previous section. Here we are only interested in fuel age interactions. It is often pointed out that the Wheeler fire appeared to stop when it reached the boundary of the Romero fire. In addition, the failure of backfiring operations in the area has been attributed to the young (14 year old) fuels.

Analysis of fire spread and weather data raise serious questions as to the validity of these assertions. First, a glance at the perimeter map (Figure 37) reveals that in places the Wheeler fire burned as much as a mile into the Romero fire, while not even coming near it in other areas. Looking at fire spread maps, it is clear that the entire southwestern front of the fire ceased active spreading on the morning of July 4 (Figure 33). Although the fire stopped spreading within the 14 year old Romero fuels, it also stopped at the same time in fuels that hadn't burned since 1932. Analysis of weather data (Table 8) indicates that this was primarily due to the influx of marine air into the area late on the night of the third.

For the duration of the fire, the coastal slopes of the mountains were subjected to high humidities that suppressed efforts at backfiring. This was noted at the time by Forest Service personnel being interviewed by the media: "...Eric Martin noted that 'there was really heavy fog on the fireline last night [7/4] and no major advances.'" (Santa Barbara News-Press, 7/5/85, pg. A-1); "Good fortune smiled on firefighters for the third straight day as mild weather and high humidity assisted efforts to smother the 6-day-old Wheeler fire. 'In fact, the weather may be too good,' said Forest Service spokesman Chuck Shipp. 'Things are so humid it's suppressing our backfires.'" (Ventura County Star Free Press, 7/7/85, pg. A-1.)

Though the young fuels left by the Romero fire may have affected the spread of the Wheeler fire to some degree, it appears that a dramatic change in weather was the primary factor in halting the fire spread in that area.

The 1972 Bear fire. Though the Wheeler and Bear fires have about a mile of perimeter in common (Figure 38), it runs along the fuelbreak on the ridge north and south of Chief Peak. It appears, therefore, that terrain and fuel type conversion were the main factors in the formation of this boundary, not fuel age. Further south, the Wheeler fire runs up against the perimeter of the Bear fire at two isolated points. However, most of the fire front (burning through 53 year old fuels) did not come near the Bear fire boundary, suggesting other reasons for perimeter formation in this area. Again, weather must be considered as the primary factor here as fire spread virtually halted with the influx of marine air and picked up again only when the marine layer weakened. Burning operations along Sisar Road, which began on the evening of July 4, were uniformly unsuccessful. The failure of this burnout cannot be attributed to young fuels, since the burning was done on the opposite side of Sisar Road from the Bear fire.

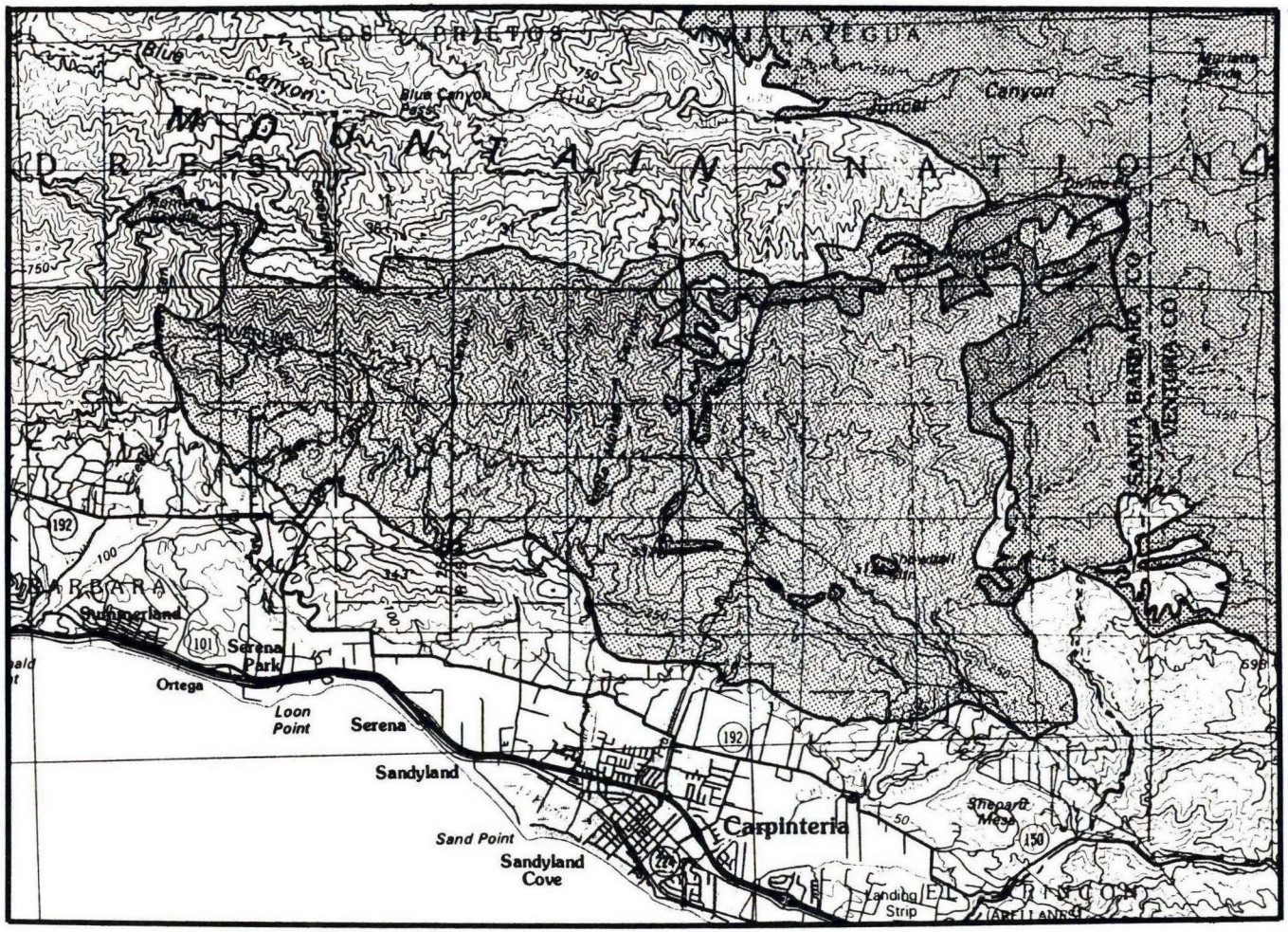
The 1978 Cozy Dell fire. The area of Cozy Dell Canyon supported seven year old fuels when the Wheeler fire began. On the evening of July 2, under the influence of strong sundowner winds, the Wheeler fire swept the canyon. Despite the young age of the fuels, fully 97 percent of the area of the Cozy Dell fire reburned (Figure 39). Obviously, even the very young age of the

fuels was insufficient to stop the spread of the fire under extreme conditions.

The 1983 Matilija burn. Of all of the fires discussed, only the Matilija burn had a clear and indisputable effect on the spread of the Wheeler fire (Figure 40). The Wheeler fire passed through Matilija Canyon on the morning and afternoon of July 3, and exhibited its most erratic and severe behavior as it did so. Still, 72 percent of the area resisted burning. This would seem to speak well of fuel age mosaics except for two things. First, the fuels were only two years old, an age level that could not be maintained over any large area. Second, even though the majority of the area remained unburned, 28 percent of the Matilija burn did reburn during the Wheeler fire. This may be partially attributed to the fact that the area had been reseeded in late 1983, but as the two winters previous to the Wheeler fire were unusally dry, the grass cover was probably not particularly dense.

With the exception of the Matilija burn, it appears that fuel age mosaics were of limited value in slowing or stopping the spread of the Wheeler fire as long as it was pushed by extreme weather. Fuels on the Wheeler fire in excess of five years old showed no significant difference in flammability from 50 or 60 year old fuels (Figure 41), and overall, within the perimeter of the Wheeler fire, the average porportion of unburned fuels hovered around five percent for all but the youngest age class. This implies that prescribed burning may be of very limited value in decreasing the flammability of chaparral fuels.

In the past, fuel age changes have been used to explain the formation of fire perimeters without considering other factors that may have been involved. Many fires stop on ridges due to the presence of fuelbreaks or the lack of sufficient heat energy to carry the fire over the top and down the other side. Looking at fire history maps without studying the terrain may lead to the conclusion that it was the fuel age rather than the terrain that affected perimeter formation, when actually the fuel age boundaries are a result of the terrain. Similarly, ignoring changes in weather can lead to erroneous conclusions concerning perimeter formation. Before concluding that age class boundaries have a large effect on perimeter formation it is wise to look at all factors that affect fire behavior.



Romero Fire

Wheeler Fire

Figure 37. Perimeters of the 1971 Romero fire and the 1985 Wheeler fire.

Scale: 1" = 1.58 miles.

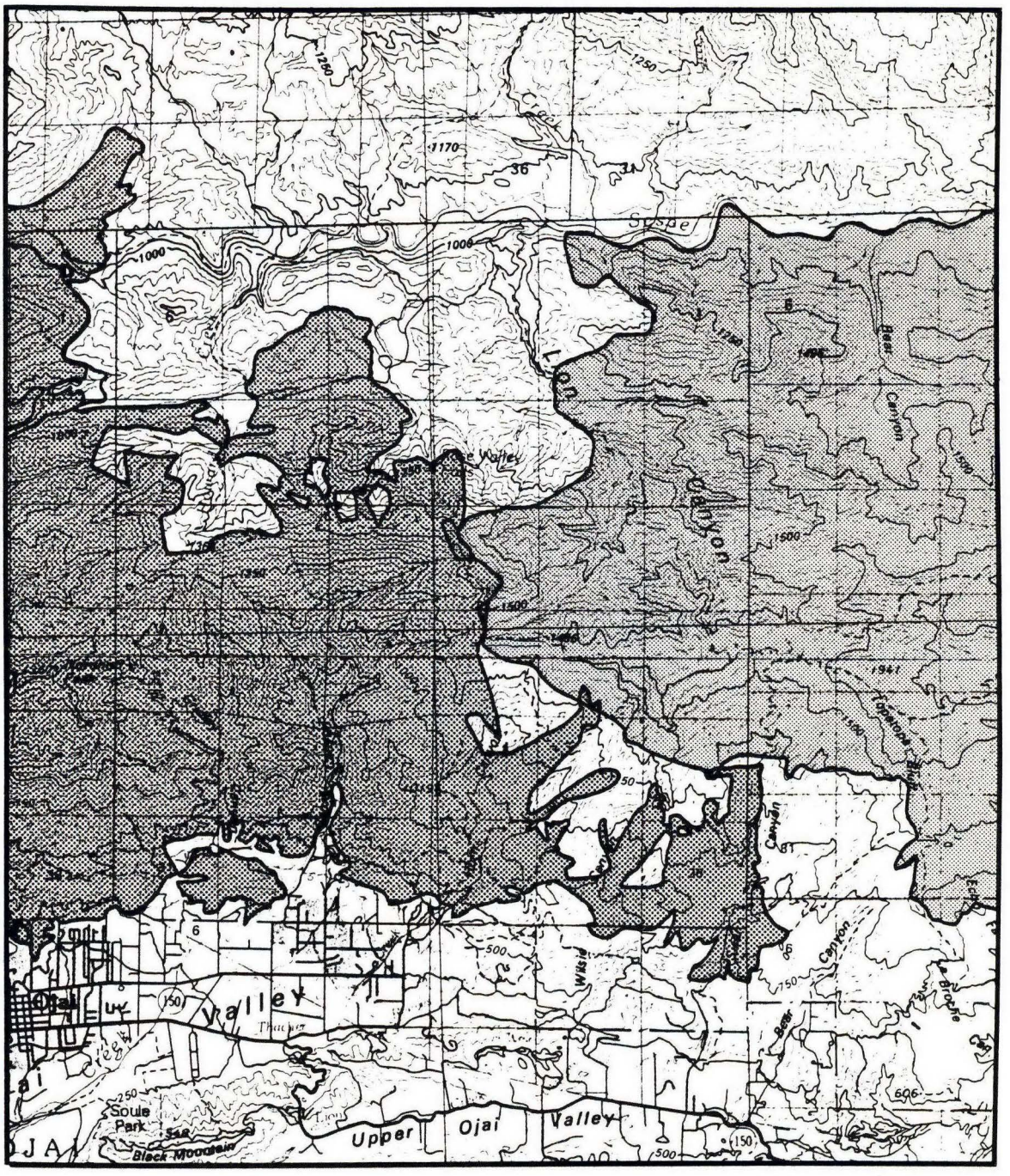


Figure 38. Perimeters of the 1972 Bear fire and the 1985 Wheeler fire.

Scale: 1" = 1.58 miles.

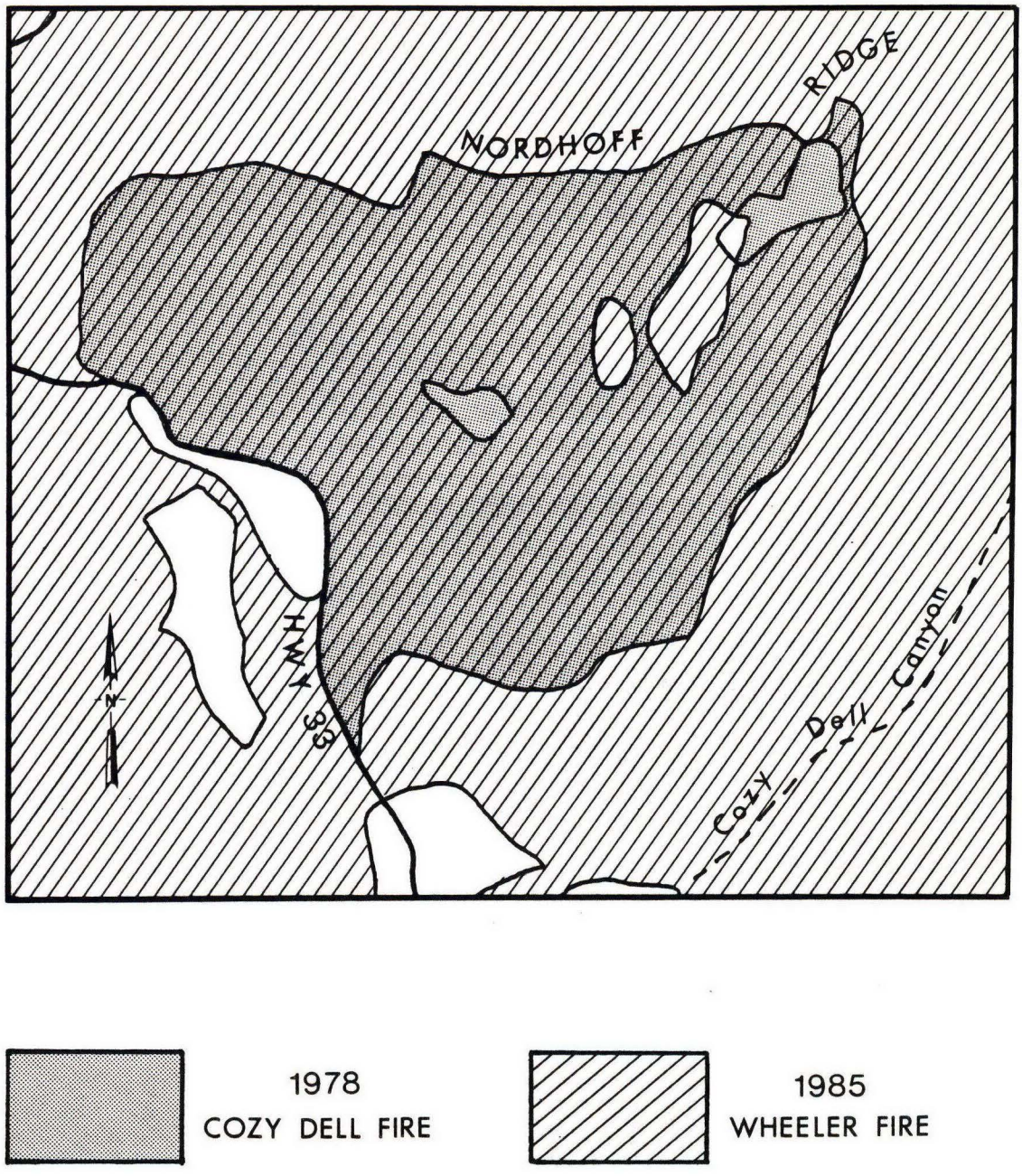


Figure 39. Perimeters of the 1978 Cozy Dell fire and the 1985 Wheeler fire.

Scale: 1" = 0.38 miles.

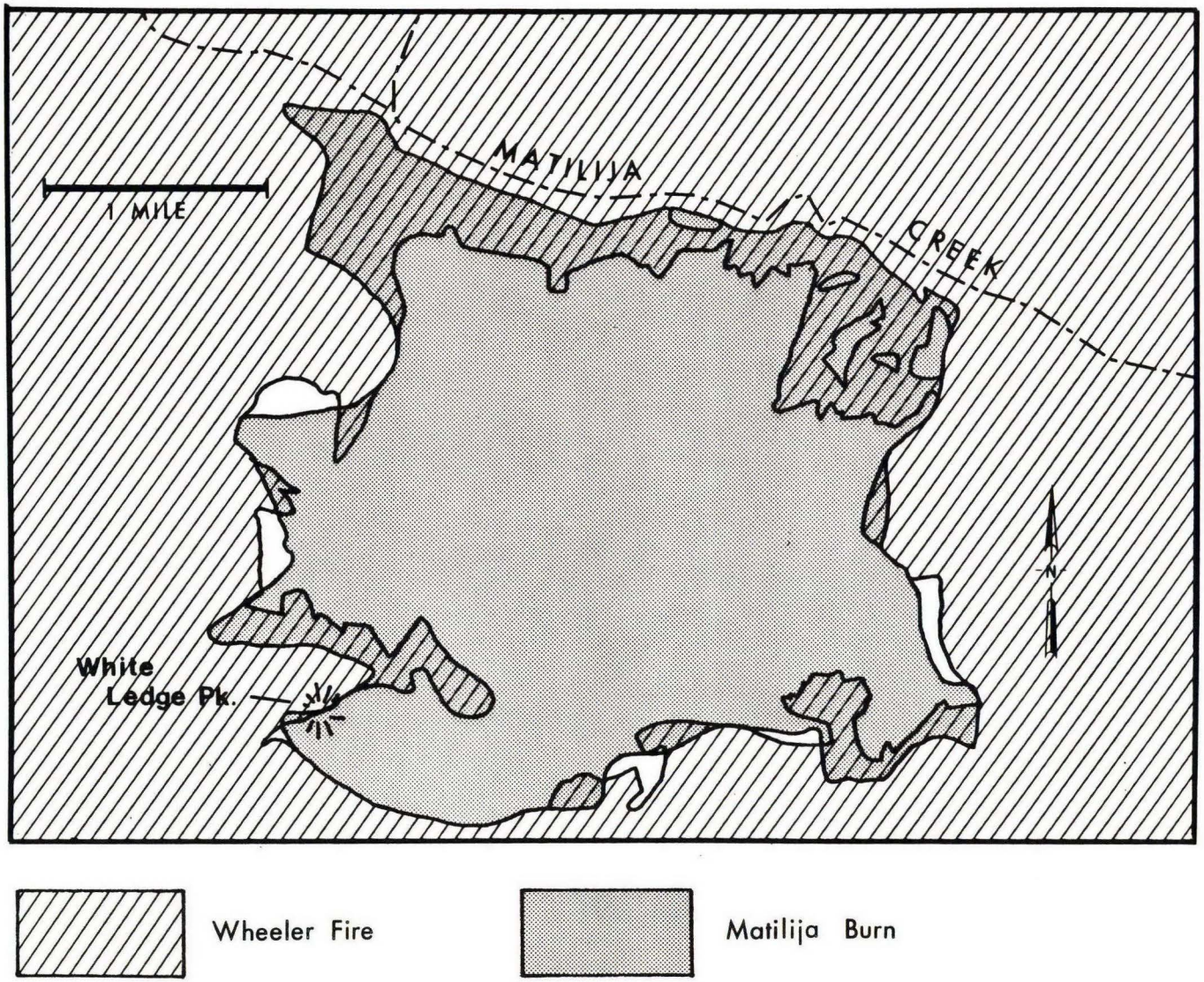


Figure 40. Perimeters of the 1983 Matilija fire and the 1985 Wheeler fire.

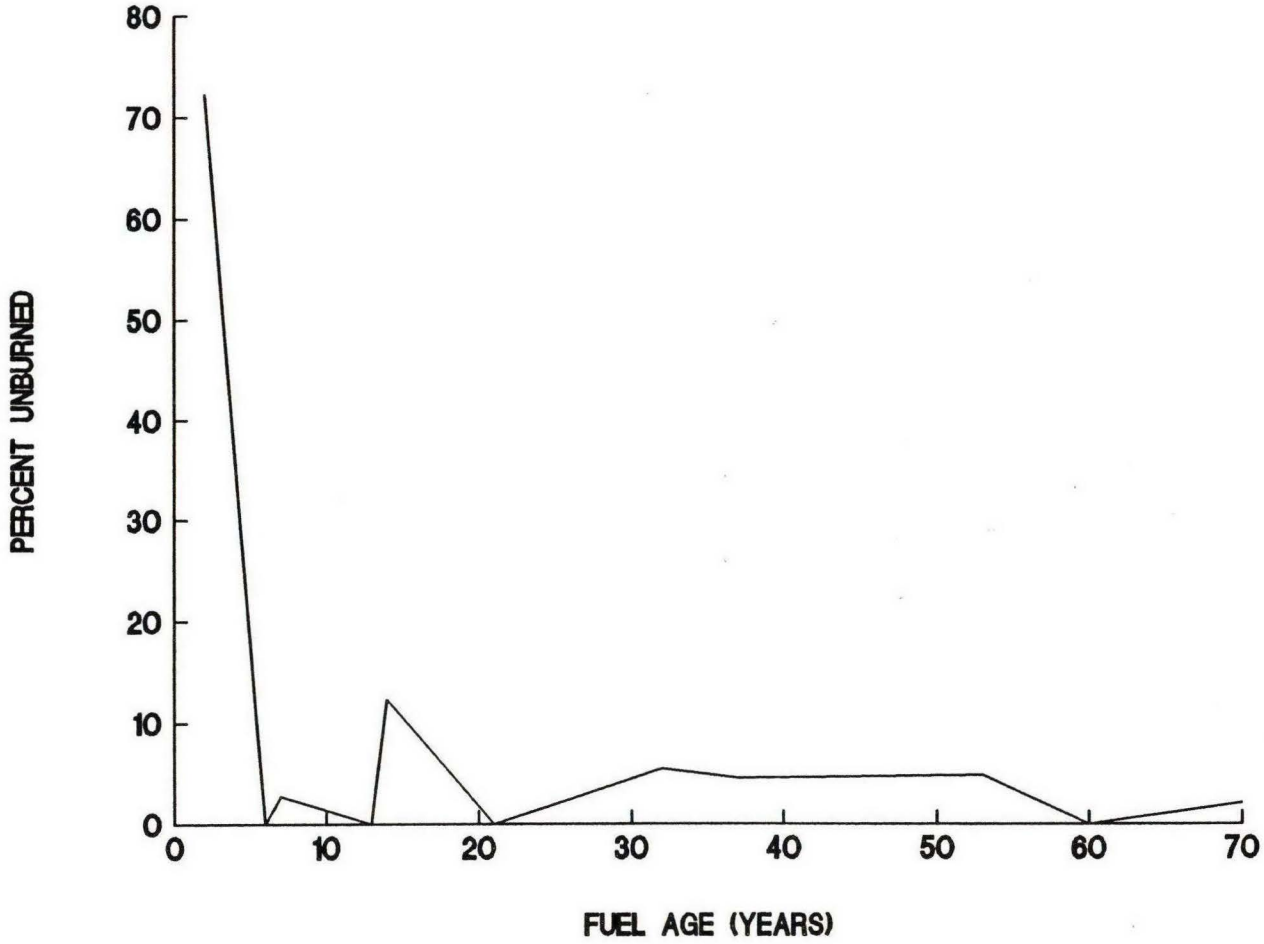


Figure 41. Porportion of each fuel age class remaining unburned within the primary perimeter of the Wheeler fire.

Terrain and suppression as fire behavior factors

Many of the influences of terrain on the Wheeler fire (such as the location of the front ranges) have been covered in discussions on their effects on weather. In this section, the focus will be on the influence of terrain on suppression efforts. Of the three elements of the so-called fire behavior triangle (weather, fuels, topography), topography is the one most commonly bent to aid suppression efforts. Fuelbreaks are generally cut along ridgelines and roads are often positioned in canyon bottoms--prime locations for suppression activities.

On the Wheeler fire the rugged topography often dictated suppression strategy by limiting access to the fire front. Only on the slopovers near Pendola Peak and north of Highway 33 and Rose Valley Road was direct attack used on the Wheeler fire. In all other areas the ruggedness and inaccessibility of the terrain or the intensity of the fire overruled the possibility or feasibility of direct attack. This was recognized early on by fire planners when they developed the Escaped Fire Situation Analysis (EFSA) for the Wheeler fire. The first three alternatives in the analysis (Table 12) suggested aggressive direct or indirect attacks on the fire in order to contain it, but were given very low probabilities of success. After the major blowup of July 3, these alternatives were no longer possible and it was felt that alternative 'E' was the best alternative for fire containment. The strategic elements of this plan were as follows:

Protect structures in Ojai front and upper Santa Paula canyons.
Halt western fire spread at Rincon fuelbreak.
Halt fire south of Potrero Seco fuelbreak.
Halt fire west of Topatopa Bluffs and Santa Paula fuelbreak.

In its essentials, this plan was followed throughout the fire with great success--helped, after July 3, by fairly moderate weather. This plan stressed firefighter safety and relied for the most part on burning out from established roads and fuelbreaks for fire control.

It was the very lack of roads and fuelbreaks that forced planners to settle on an alternative over 100,000 acres larger than Alternative 'A' in the EFSA. With the exception of a single dirt road in Matilija Canyon, the entire area between Matilija Dam and Potrero Seco lacks any access or usable suppression features. Due to this and the extreme ruggedness of the terrain, no suppression activities were considered feasible and the entire area (perhaps 50,000 acres) had to be virtually "written off" once the fire had entered it.

Table 12. Escaped Fire Situation Analysis alternatives for the Wheeler fire, developed on July 3 and 4, 1985.
Source: Wheeler fire EFSA

PLAN	ESTIMATED ACREAGE	CONTROL TIME	PROBABILITY OF SUCCESS
A	19,000	2400 July 6	20%
B	15,000	2400 July 7	30%
C	13,000	2400 July 8	40%
D	99,200	2400 July 10	70%
E	122,000	2400 July 12	80%
F	125,000	2400 July 13	80%
G	130,000	2400 July 14	90%
H	131,000	2400 July 15	90%

Burning out operations.

By its third day, the Wheeler fire had been divided into branches. By the time that burning out operations were fully under way on July 6, the fire consisted of six branches, each with its own burning out assignments. Figure 42 indicates the locations of the branches as of July 6 (they changed somewhat later in the fire) and Table 13 outlines their respective burning assignments.

The success of burning out operations was very closely tied to when and where the burning was conducted. Burning out operations accounted for nearly 50 percent of the Wheeler fire perimeter (Table 14; Figure 43). Burning operations conducted on the coast side of the front ranges were often hampered by a deep marine layer and out of 26 miles of burnout line attempted, only 16 miles actually ended up forming the final perimeter of the fire (Figure 43). Burnouts along Sisar Road on the east edge of the fire and Camino Cielo on the west edge of the fire were the least successful. In all only about 20 percent of the acreage burned out on the Wheeler fire occurred on the coastal side of the mountains.

Success rates were much higher in the inland areas, where 29 out of 31 miles of burnout line attempted ended up forming the final perimeter (Figure 43). In fact, burning out went so well that on the afternoon of July 4, a brand from burning out operations along Highway 33 jumped the road and created a 650 acre slopover. Between July 5 and July 15, over 15,000 acres were burned out in the interior areas, over 80 percent of the total on the fire.

Fuelbreaks.

Fuelbreaks played a valuable, though mixed, role in the Wheeler fire. On the one hand, fuelbreaks were vital for burning out operations especially along Laguna Ridge and the area between Monte Arido and Potrero Seco (Figure 44). In all about 19 miles, or nearly 20 percent of the Wheeler perimeter was formed by burning out operations from fuelbreaks (Salazar and Gonzalez-Caban 1987). On the other hand, the fuelbreaks themselves posed little obstacle to the advance of the fire, as every fuelbreak that the Wheeler fire encountered during its first three days was breeched. There are two main reasons for this. First of all, during the first three days of the fire, nearly all forces were committed to evacuations and structure protection in the Ojai area, and no forces were available to man the fuelbreaks. Secondly, weather conditions and fire behavior were so severe during the first days of the fire that it is very unlikely that backfiring could have been safely attempted.

In all, the fuelbreak system functioned as intended during the Wheeler fire, providing access to the fire line and serving as a line from which burning out operations could be successfully conducted. But as Salazar and Gonzalez-Caban (1987) suggest, a more extensive fuelbreak system in the central area of the fire

might have allowed for greater access to the fire and may have reduced the total acreage consumed.

Summary of Factors Affecting Wheeler Fire Behavior

The Wheeler fire, though man-caused, was a result of the interacting flux of conditions in the environment, each element of which contributed in one way or another and to one degree or another to the fire's behavior and final perimeter. It was only with the particular combinations of these elements that the Wheeler fire became what it was.

Drought during the winter of 1984-85 contributed to the low live fuel moistures that brought the chaparral fuels to a high level of potential flammability so early in the fire season. In combination with the occurrence of a strong subtropical high aloft, the danger of an explosive fire became extreme. High temperatures and low humidities, combined with the heavy fuels, difficult terrain and lack of local initial attack forces contributed to the fire's escape. As long as the weather remained severe, with nighttime sundowner winds and little if any marine layer, rates of spread and fireline intensity were too high to allow any effective suppression activities, and the fire burned through all fuel types and over any terrain. As the high weakened, marine air was able to penetrate the coastal areas of the fire, virtually stopping the fire's spread there. In the inland areas, steep terrain and the lack of suppression features such as roads and fuel breaks forced suppression forces to sacrifice large areas to the fire. Burning out operations were strongly influenced by the presence of the marine layer, and proceeded with greater success behind the front ranges for the duration of the fire. Fuel age boundaries appeared to have little effect on the spread or perimeter formation of the Wheeler fire.

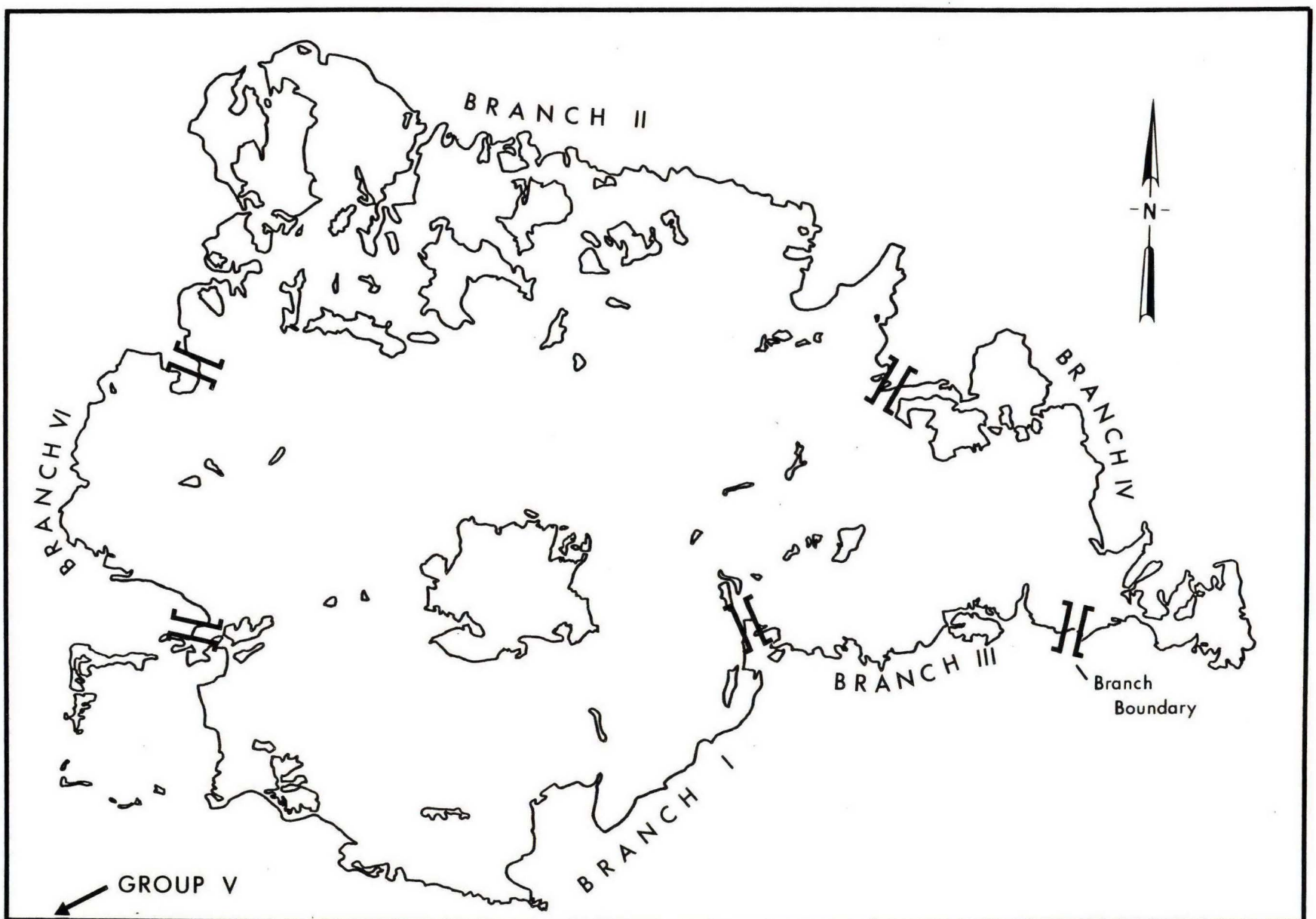


Figure 42. Branches of the Wheeler fire as of July 6, 1985.

Table 13. Burning out assignments for the five branches of the Wheeler fire.

BRANCH	ASSIGNMENT
I	Burn out Camino Cielo fuelbreak down Sutton Canyon to Snowball Mtn. (The Laguna Ridge area had been fired by Ventura Co. forces on July 4-5.)
II	Burn out along Highway 33 from Rose Valley Road to Potrero Seco. Begin burning out operations on Monte Arido fuelbreak north from Monte Arido to Potrero Seco.
III	Patrol line. No burning out operations.
IV	Burn out Rose Valley Road east. Burn out along Sisar Road toward Chief Peak.
GROUP V	Prepare for evacuations in Carpenteria area.
VI	Contain slopovers. No burning out.

Table 14. Porportion of Wheeler fire perimeter formed by different factors. This table is only a rough estimation as more than one factor may contribute to perimeter formation.

CAUSE	LENGTH (miles)	PERCENT OF TOTAL PERIMETER
Burnouts	45.0	47
Fuel Type Change	13.5	14
Weather Change	10.5	11
Direct Attack	9.5	10
Obstructions	9.0	9
Unknown	8.5	9
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TOTAL	96.0	100

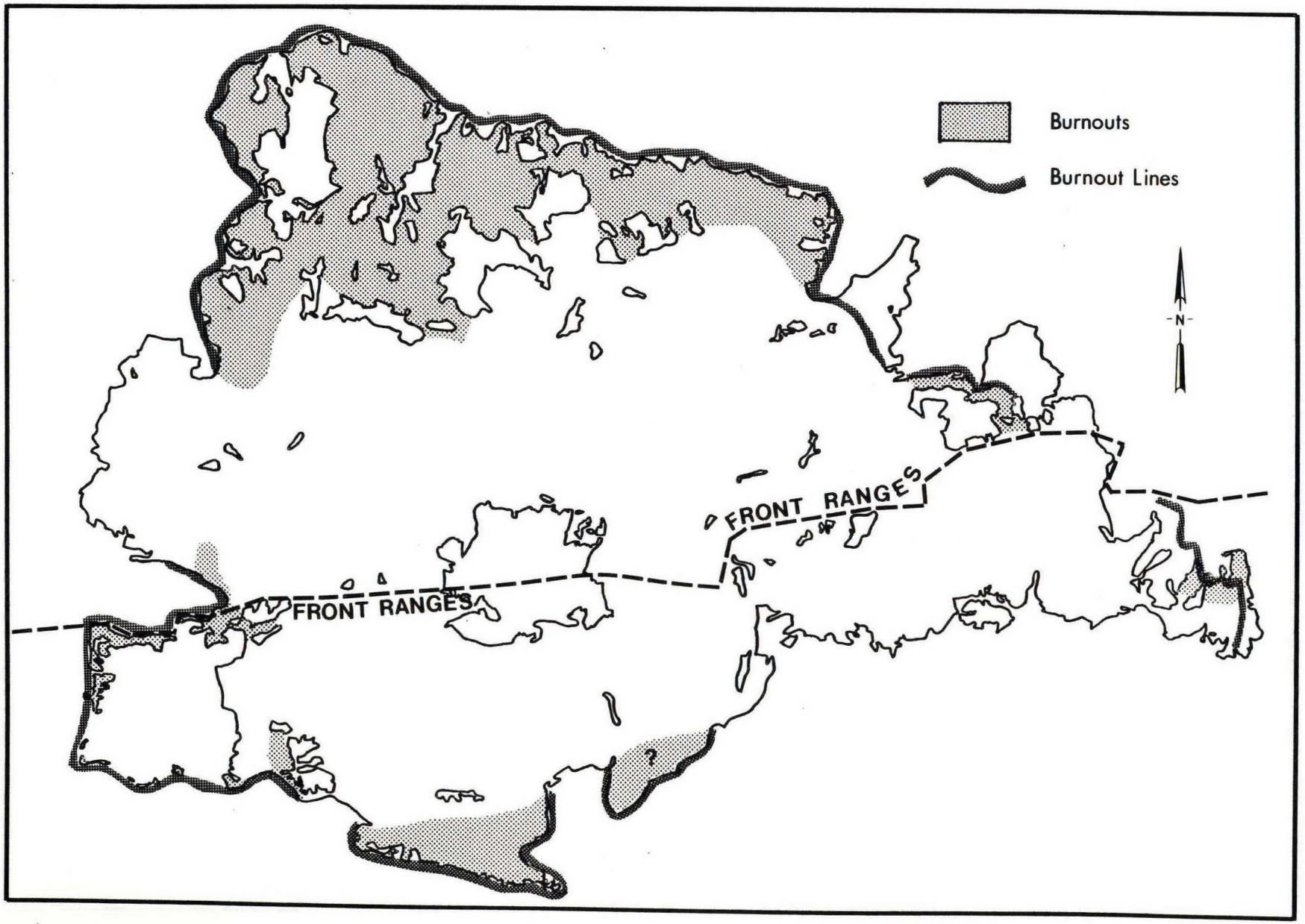

Figure 43. Areas burned-out during the Wheeler fire. Note the greater level of success in burning-out behind the front ranges.

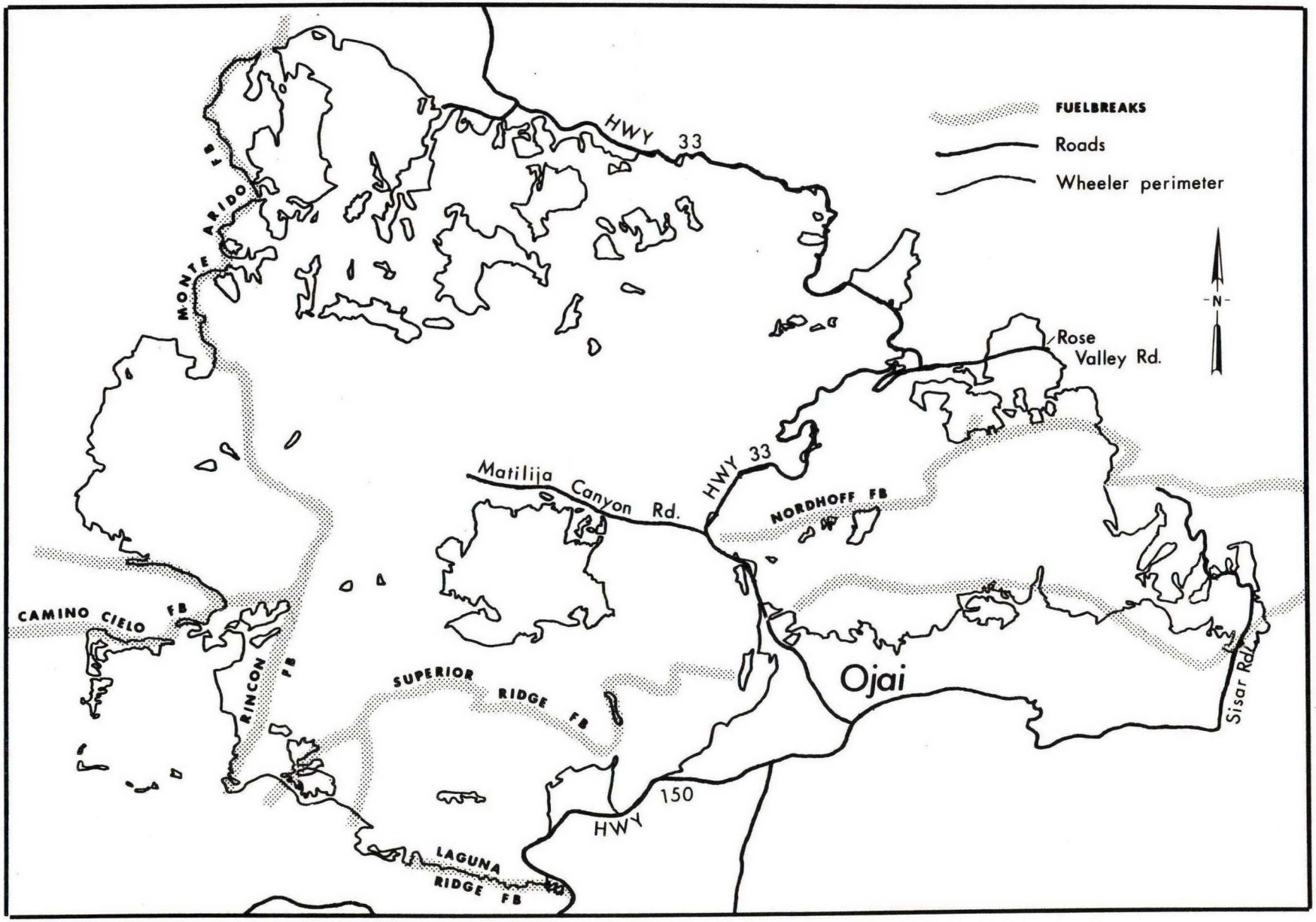

Figure 44. Major roads and fuelbreaks in the Wheeler fire area. Note the lack of suppression features in the northwest portion of the fire.

CONCLUSIONS

Implications for Further Fire Behavior Research

The value of a 'gestalten' approach to fire behavior

Science has a long history of reductionism, and indeed, it is one of the major foundations of scientific philosophy. There is nothing inherently wrong with this. However, many systems (particularly ones with many components) possess emergent properties; that is, properties that are not apparent from separately analyzing the parts of the systems. Watches and human brains have emergent properties; they are more than just collections of cogs or brain cells. The same is true for fire behavior. The complex interactions of fuels, terrain and weather (constantly changing over time and space) are synergistic in nature, and give rise to behaviors that may not be seen by merely summing their separate influences. Reductionist research, while extremely valuable, runs the risk of oversimplifying fire behavior and can be misleading, assigning undue importance to some elements while ignoring others. On the other hand, research that focuses on the gestalten nature of fire behavior attempts to address or at least recognize its emergent properties.

In the final analysis, it becomes clear that the Wheeler fire was not the monolith that fire perimeter maps always suggest, but rather almost a living being, reacting to and acting upon its changing environment. Fire behavior, in this study, emerges as a gestalt, a complex whole that cannot be understood through its parts alone. That is the importance of the type of analysis conducted on the Wheeler fire: it attempts to rejoin these parts, stressing how they influence each other and give rise to the thing we call fire behavior. Further fire behavior research should be conducted with this thought held firmly in mind.

Topics for further study

Though this project revealed many things about fire behavior, the sheer complexity of fire behavior made it inevitable that it would also raise a number of questions for which there are, as yet, few answers. Many of these have been noted previously in this report, but a brief listing of the major questions may help to focus attention on them.

1) Is it possible to consistently quantify aspects of fire behavior in terms of weather parameters such as temperature and relative humidity? If so, what is the nature of the relationship?
2) In exactly what way do rapid changes in temperature and relative humidity affect the burning characteristics of the fuel bed? Can these effects account for rapid changes in fire behavior?

3) What is (are) the catalyzing mechanism(s) of blowup conditions in the Wheeler fire area? Are they predictable?
4) What are the actual physical characteristics of the chaparral fuel bed and which of these influence flammability? Do new fire behavior processors need to be developed to accommodate chaparral fuels?
5) What exactly is the value of fuel age mosaics in fire suppression?
6) How do rainfall cycles and fuel age trends affect the occurrence of severe fire years? What are the operative mechanisms?
7) Is it possible to define fire management plans and fire behavior models for specific geographic areas based on a knowledge of historic fire behavior patterns? How should these "fire behavior provinces" be defined?

Management Implications of Historical Fire Behavior Studies

Though much can be learned by examining the behavior of the Wheeler fire alone, it is merely one piece of the puzzle that constitutes the fire environment of that area of the state. One must examine the entire historical spectrum of large fires in the area before repeated patterns of fire behavior will begin to emerge. Only then will we begin to obtain an image of the nature and potential of the fire environment.

The Wheeler fire area, just like every other area of the globe, supports a unique interaction of climate, vegetation and topography. Responding to this uniqueness, fires in the Wheeler fire area may exhibit patterns of behavior experienced no where else. Indeed, the Wheeler fire could not have occurred in San Diego County. That is not to say that a fire of its size could not occur, but that a fire exhibiting its patterns of behavior would have been precuded by a lack of the very terrain and weather configurations that gave rise to the Wheeler fire.

This uniqueness must be accounted for in fire management planning and fire fighting strategy if fires are to be met on their own terms. But what has this study revealed that is of direct value to the fire manager? What are the characteristics of the fire environment in the Wheeler fire area? Unfortunately, even though our knowledge of the fire history of the area is relatively good, we lack sufficient data to do more than point out a few general patterns that have emerged. Still, these generalities have value, especially to personnel unfamiliar with the area and its particular combination of fuels, weather and terrain. Armed with a knowledge of common fire behavior patterns of the past, it should be possible to better develop strategies for fighting fires in the future. A list of the more important patterns follows.

Rainfall and fuel age trends. Analysis of the fire history of the main division of the Los Padres National Forest since 1950 revealed a distinct pattern of large fire occurrence.

Generally speaking, large fires were most likely to occur during post-fluvial drought years when the level of young fuels on the forest was low. Severe fire years in 1964, 1966 and 1985 followed this pattern. In the future, it may be possible to use this type of analysis to predict the potential forest-wide large fire hazard.

Subtropical high aloft. This is far and away the most common synoptic weather type for large fires in the Wheeler fire area. Only the Romero fire clearly occurred under a different regime. This differs from other areas of the state where the Santa Ana condition may give rise to the majority of severe fires. The high temperatures and low humidities that occur in the interior during this weather type, combined with the rugged topography, often give rise to erratic and extreme fire behavior.

Blowup conditions. The three largest fires in the area (the Matilija, Wheeler Springs and Wheeler) all exhibited varying levels of blowup behavior. In each case, the blowups began in the late morning or early afternoon and ceased by late evening. The mechanism(s) driving this condition remain unknown, but blowups seem to occur most often under conditions where synoptic wind patterns are weak. It is possible that blowup conditions arise from particular combinations of local factors, among which terrain is likely important. In the case of the Matilija and Wheeler fires, blowups began soon after the fires had entered a large, narrow canyon. Blowups appear to spread either to the east (Wheeler Springs, Matilija) or to the west (Wheeler). There are no known instances of fires in the area spreading to the north or south under non-sundowner blowup conditions. Still, further research is needed before definite conclusions can be drawn.

Sundowner winds. Almost every large fire in the area was affected by sundowner winds, giving rise to extreme behavior on the coastal side of the mountains. With the exception of the Romero fire, these winds appeared to occur under a subtropical high aloft condition. Since sundowner winds are hard to predict and give rise to dangerous fire behavior, primary concern should be given to preventing fires originating in the interior from spreading to the coastal side of the mountains where they may advance on populated areas.

The marine layer. The presence or absence of a strong marine layer along the coast can spell the difference between safety and disaster for communities such as Ojai and Carpenteria. In all cases where the marine layer was present, fires were incapable of much activity on the coastal side of the mountains. However, the front ranges are an effective barrier to marine air penetration and fires often continue to burn actively in the inland areas despite high humidities along the coast.

Topographic features. Besides the effects on the marine layer and sundowner winds, a few patterns of fire behavior and topography were observed. Both the Wheeler Springs and Wheeler fires stopped of their own accord along Dry Lakes Ridge. Though the Wheeler fire later spread across to the other side, this ridge may be a prime location for a fuel break, taking advantage of its apparent role as a natural boundary. Consideration should be given to constructing a fuelbreak along the ridge system that runs

from Sespe Gorge west towards Monte Arido. A fuelbreak there might have reduced the total acreage consumed during the Wheeler fire. Also, the ridge running north of Chief's Peak has formed the boundary of fires in 1932, 1948, 1972 and the Wheeler fire in 1985. Though a fuel break already exists there, better awareness of its historical value may increase its value in future fire suppression.

Fuel age boundaries. Fuel age boundaries were not a significant factor in perimeter formation on the Wheeler fire, and do not have appeared to have hindered the 1948 Wheeler Springs fire. Fuels greater than five years old appear to be as flammable as older fuels when weather conditions are extreme. A re-evaluation of prescribed burning policies with respect to fuel age modification may be desirable.

Multiple fire fronts. To someone from another part of the state, the multiple front nature of most of the large fires in the Wheeler fire area is the most perplexing and unusual aspect of the fire environment. Each of the three largest fires in the area exhibited multiple fronts at one period or another. Generally, these develop into east and west fronts. North/south divisions were more common during the first day or so of these fires; with the influx of the marine layer, the southern front usually died out. These multiple fronts arise due to interactions of the rugged, generally east/west trending terrain and the typically north (sundowner) or south (coastal) winds. This situation poses serious control problems as relatively quiet flanks may suddenly develop into active fronts inaccessible to suppression forces. It also necessitates dividing suppression forces over large areas, causing logisitcal problems as happened on the Wheeler fire.

Unfortunately, quantified weather and fire spread data, such as was available for the Wheeler fire, was lacking on most of the historical large fires in the area, so that many recurring patterns that may exist remain undiscovered. Still, the some of the patterns that do emerge are suggestive. Fires burning near the front ranges under a subtropical high aloft should alert the fire manager to the potential of both sundowner winds and extended periods of extreme behavior. Also, if the historical patterns of blowup conditions are more than mere chance, large, active fires entering deep, narrow canyons during the late morning hours may be warning signals of potentially extreme fire behavior.

Further Research Needs

We have only barely begun to outline the nature of the fire environment in the Wheeler fire area. Lacking quantified and accurate weather and fire spread data for all but the Wheeler fire, we cannot make more than general historical comparisons of the relationships between fire spread and environmental conditions. The establishment of quantifiable patterns of fire behavior for the Wheeler fire area will not be possible until a coherent body of observed fire behavior data has been collected. Many of the seeming relationships discussed in this paper may eventually prove unimportant, but it will not be until more fires in the area are accurately documented that we will be able to really test their validity.

The value of a well documented fire behavior history could be immense to fire managers and fire behavior officers. Confronted with a wildfire, the fire behavior officer would be able to more clearly evaluate its potential behavior based on the historical behavior of other fires in the same location. With such a foundation, the fire behavior officer may be able to indentify significant suppression features useful in earlier fires, with the potential for realizing considerable savings by allowing for more accurate evaluation and implementation of workable fire suppression strategies. With a firm historical foundation to stand on, fire managers, both veteran and inexperienced, would gain a better understanding of the specific factors that contribute to severe fire behavior, escapes and blowup conditions in their particular geographic area. Such "warning signs," when they become recognized, may allow for swifter, more certain decisions that may prevent wasted effort or even save lives. Such a body of firm historical data has the further advantage of allowing new personnel to become familiar with the peculiar fire behavior potential of an area without having to "re-invent the wheel." Of course, nothing can replace years of accumulated experience, but at the very least, such a system could prevent the loss of knowledge that often accompanies the retirement of experienced fire personnel. It may also be possible to incorporate much of this information into a computer data base that will allow quick comparison of similar environmental conditions and the fire behavior that resulted.

Unfortunately, there is today a severe lack of any standard and consistant method of collecting, preserving, organizing or evaluating relevant fire behavior data. Some cogent data is collected, but it is gathered for immediate use, without the realization of its potential value for post hoc fire analysis. Such data often lacks vital pieces of information, such as the location or time it was collected. Accuracy, particularly of fire spread data, may be insufficient for use in analysis. Further, there is no consistent method for storing this data. Much is merely discarded or stored in some government warehouse, never to be seen again. There is not yet a general realization among fire personnel of the valuable information being lost; information that if properly put to use may eventually make their job that much easier.

In this sense, the Wheeler fire was a fluke; though little of the existing data had been put to any use after the fire, much was still available and accessible. And when necessary information wasn't available from one source, there was usually another source elsewhere. But without the development of a standardized methodology for collecting and handling such data, fires such as the Wheeler will remain flukes and vital opportunities for studying fire behavior and its causes will continue to be lost.

POSTSCRIPT

One question is always asked after a conflagration fire in California: Can it happen again? The answer, in this case, is not only that it can, but also that it will. It is only a matter of time. As long as there is chaparral there will be large wildfires; that is an ecological fact of life in California. But that doesn't mean that we have to be unprepared to meet it when it happens. The more we know about the conditions that give rise to large fires, the better we will be able to predict their occurrence and behavior.

Based on known historical patterns, it is possible to advance a hypothetical scenario for a future fire in the Wheeler fire area that, while decidedly not intended to be a cast iron prediction, is certainly plausible. Though entirely fictional, the following "narrative" does point out the potential value of knowledge of historical fire behavior.

The year 2021: The Wheeler fire revisited

The date is August 8, 2021, a Sunday. It has been 36 years since the last big fire in the country behind Ojai, but it is still possible to find an oldtimer who is happy to recount the towering flames and valiant efforts of the firefighters during that hot July way back in 1985. "Hasn't been a big one in the area since, guess we're about due, I reckon," might be his assessment.

The winters of 2018 and 2019 were wet years. Over 30 inches of rain fell in Ojai both years. But only 12.52 inches were recorded for the 2019-2020 rainfall season, and most of that fell before January 20. In July, live fuel moistures had dropped to 55 percent, 20 percent below normal. On August 5, the weather, which had been cool and foggy along the coast all summer, suddenly changed. An upper level high over the eastern Pacific began moving east. Temperatures in the inland areas jumped by 20-25^{o}. By August 7, there was no marine layer to speak of and Santa Barbara sweltered under record 110^{o} heat. The subtropical high aloft had become established over Nevada and California and showed no signs of weakening. Fire personnel at Ojai and Wheeler Springs, knowing full well how critical the situation was, waited tensely for the call.

It came at 1541. A fire was reported south of Rose Valley Road, near Rose Valley Falls. Cause: arson. By the time that the Wheeler Springs engine arrived on the scene at 1555, the fire had grown to five acres and was spreading actively upslope toward Chief Peak. The district FMO immediately mobilized for a major campaign and ordered a Class I team.

At 1835, the thing that everyone feared happened. Sundowner winds commenced all along the front ranges. The fire (dubbed the Rose Valley Fire) immediately spotted across the fuelbreak between Nordhoff and Chief peaks and began a rapid run down Senior Canyon toward Ojai. But the firefighters were not

unprepared. Most of the the residents had been advised to prepare for evacuation within an hour after the fire had begun and firefighters were posted all along the north side of Ojai. During the night, the fire was halted on the outskirts of town and held east of Highway 33.

On the morning of the 9th the fire spotted across Rose Valley Road and began burning across Sespe Creek into 88 year old fuels. Firefighters were evacuated from the northern section of the fire when fireline intensity began to increase. Just after noon, with temperatures standing at 106^{O} and relative humidity at 19 percent, the fire blew up. The District FMO, who had always wondered what the major runs of the Wheeler and Matilija fires had been like, finally found out. In six hours, the Rose Valley fire burned to Willett Hot Springs, a distance of seven miles. From noon to midnight on August 9, the fire nearly guadrupled in size, from 11,600 acres to 43,100 acres.

On August 10, the fire jumped Highway 33 north of Wheeler Gorge, but was contained by burning out operations conducted from the fuelbreak on Dry Lakes Ridge. The east front of the fire had entered the old Sespe Condor Sanctuary, burning toward Topatopa Peak. Sundowner winds continued on the night of the 10th, driving the fire into Sisar and Bear Canyons. Thankfully, this would be the last appearance of sundowners on the fire.

By the early morning of the 11th, the upper level high had begun to move east and marine air invaded the Ojai Valley. The south flank of the fire died down, never to rise again. The moderating weather helped burning out operations and line construction in the inland areas and on August 16, the Rose Valley fire was declared controlled at 79,122 acres.

In the end, firefighters could not say that they had prevented the fire, nor really stopped it. But armed with a knowledge of the historical behavior of large fires in the area, they were able to accurately second guess it. The positioning of forces at Ojai, along with the rapid evacuations, held losses to a minimum. More importantly perhaps was the accurate assessment of potential blowup conditions and the evacuation of two hot shot crews and a dozer strike team from the path of the fire. As a sign posted on a tree in fire camp said, "forewarned is forearmed."

Hopefully, this scenario will never be enacted, but one like it is inevitable some time in the future. The better prepared we are to meet it, the better we will be able to deal with it.

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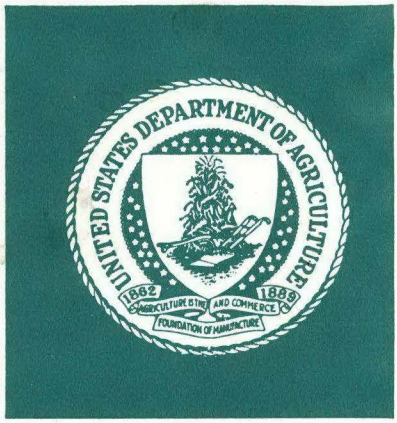

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